Generative AI in STEM Education

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Abstract: —Our objective is to make STEM education more gender inclusive for women, to achieve their career aspirations through the application of Generative AI technologies. This is the result from our investigation on Software Engineering and AI [5], where we were studying the application of intelligent chatbots to design software and have applied it to address a more gender inclusive science, namely the Gender Inclusive Chatbot (GIChatbot). The more general scope of our investigation is how to design responsible Generative AI technology for gender equality, i.e., address how Generative AI technology supports inequalities [3]. One of the aims of this project is to tackle diversity and inclusion of girls in science through the digital living mentoring and learning hub. The project builds on bringing informal learning into the classroom, driving engagement through co-design thinking principles building on the practical informal maker-style activities to develop resilience in learners and mentoring guide to provide important guidance and the process of "instrumententalising". Hence, to take ownership of materials and adapting and repurposing the artefacts into 'instruments'. These 'instruments' of bring an act of learning to an owned artefact, enable capacity building [7]. The Research Methodology and Approach as well as the Originality and innovative aspects of the research programme will also be addressed, as well as a scenario of usage of the chatbot "mentor-me" as an illustrative example of application of the research concepts.

Keywords: —Chatbot, Gender Inclusive Science, Generative AI, IoT, STEM.

1. Introduction and State of the Art

The technology divide and skills gap impacts women more significantly than men due to the barriers for women to take a career role in Science, Technology, Engineering and Mathematics (STEM). With the 4th Industrial Revolution (4IR) many jobs will be automated and new jobs and careers will emerge requiring further digital skills and knowledge. The 4IR could smash gender inequality or deepen it. In an analysis of the job roles that are at risk due to 4IR may impact women [1] [2] further, increasing inequalities. As AI transforms global production, skilled workers with college degrees will emerge the winners: but the benefits will be distributed unevenly, and it is primarily women – from high school dropouts to college graduates – who find the odds heavenly stacked against them.

The digital divide is compounded by a digital literacy gap in the lack of basic technological skills, which poses an obvious impediment to both access to and use of ICTs. Even when women have affordable access to the Internet and the skills to make use of it, they are often confronted with:

a) a lack of online content relevant to their experience, context and language, and
b) a hostile and unsafe online environment, likely to discourage them from using certain websites, services, or features [11].

Furthermore, research in equality studies often oversimplifies the context; the research assumptions and methods applied fail to address the social structures that may cause the inequalities challenged by the study of women's low presence in computing. This inequality is further perpetuated by industry's selection process, reinforcing gender discrimination as a function of historical accident. A particular stereotype identity has emerged of the antisocial, mathematically inclined men forming the core representation of the expected workplace for programming; this stereotype is often referenced as contributing to why women do not pursue a career in tech. This is not to imply that females are not mathematically inclined. Even if high verbal and mathematical aptitudes are important for success in computing careers, there are generally more women than men with these high scores. The lack of women in these fields is therefore down to other factors: it is plausible that mathematically talented females who are equally verbally talented are drawn to equally ambitious careers outside of STEM fields [19], especially in careers typically known as ``people fields'', or where women think their career will help others and benefit society.

The *educational gender equality paradox* is that this under-representation is higher in countries with high levels of gender equality, where the state supports educational and empowerment opportunities and generally promotes girls' and women's engagement in STEM fields. This is explained by stating that the more equal society, the more choices are available to women. The perceived social and cultural context to achieve a successful career, in certain science fields, require long working hours, an antisocial, competitive working environment that often appears to lack or explicitly identify with community values (social good) and is portrayed as isolating rather than collaborative. Conversely, when STEM careers are presented as providing community value, female interest increases. Similarly, when a collaborative approach to computing is promoted, such as the use of pair-programming, women persist in their study of computing. Hence, certain pedagogical approaches to teaching and learning about technology can support efforts in bridging the gender gap. However, culture and values, either perceived or real, impact women's decision, especially in more gender-equal countries where other equally fulfilling careers are an option. But for the most vulnerable female learners and young and adolescent females the impact on not engaging with digital technologies and benefiting from improved digital skills may push the gender inequality gap back by years.

On the one-hand key drivers identified by the OECD and the human rights illustrate the need to reshape engagement but on the other hand the highly male dominated digital technology space limits through enculturation a deeper digital divide. This will only be exasperated by the automation through AI. This challenge for gender equality and equal opportunity in society and the workplace has been further highlighted during the COVID crisis, as more women's jobs are at risk and the clear unequal home responsibilities placed on women resulting in both career and financial disadvantage.

While the research identifies the gaps and challenges and the differences, there has not been a clear approach to understand what interventions would work to improve the engagement of vulnerable young women into STEM and in particular computing and programming. Women are underrepresented in the fields of Science, Technology, Engineering and Mathematics (STEM) in most countries [18], [19]. This was demonstrated in several surveys investigating the proportion of women in STEM fields for specific population [10].

However, women are key to the creation of Computer Science from the infancy. Ada Lovelace, for example, was widely regarded as the first-ever programmer, whose name was given to the important programming language we use today. The very term of "Software Engineering" (SE) was coined 50 years ago by Margaret Hamilton, a pioneer NASA woman who led the Apollo Moon landing software project. Her insights pioneer many SE fields, ranging from testing to verification. Despite their great achievements, however, nowadays we see a huge gap in the industry where women are not inclusive in engineering and IT jobs. However, women are still underrepresented in STEM even if such gaps are not the result of differences in intellectual ability. What factors explain why girls do not pursue education and careers in STEM career at early age, are namely:

1) negative stereotypes about their intellectual abilities and

2) stereotypes about people who work in STEM career as being nerdy or socially awkward.

Problems - There is something wrong in our education system, that at some point, girls who were enthusiastic about technology gives up the career ambition for some unknown reasons. What factors put them off from achieving higher in the technology domain are yet to be found. Had teachers and educators known these factors earlier during the process, we could take appropriate steps to intervene and close the gender gaps in STEM.

Challenges - One of the main challenges is that learning off-school are harder to observe, hidden from the schoolteachers. It is also much harder to control what and how students are doing as compared to their progress in curriculum have been monitored and assessed on-site at school. However, nowadays learning materials are often available on the Internet and students cannot learn everything from the school. Especially, an opportunity is that the use of mobile devices and apps enables the new-millennium generation to engage with the wider study.

Research Questions - Why young girls at a very early stage of study are put off from STEM subjects? How to attract young women to study STEM subjects using the mobile technology? What measures can be put in place to understand and assess the gender-inclusiveness in the STEM curriculum? Where are the gaps between what employers need and what the younger women is capable of to improve their employability?

In a world where technology is on the increase as part of engaging across communities from education, work and social encounters, a continuing challenge both nationally and internationally is the continuing gender gap e.g. girls are less likely to take for example computer science further. The drop in STEM is seen at GCSE level. Studies show that many girls are dropping computer science at year 10. There are several initiatives currently running that attempt to address this challenge. However, many of these initiatives are designed to support young and older adults e.g. 18+ . While these efforts are important, addressing secondary school engagements will provide opportunities for girls to find experiences and value in science that will support better life choices. The inequalities and challenges faced both nationally and globally have been identified by Perez [8]. The 'Invisible Women' goes beyond identifying the challenges in science, but it is an important place to start. The findings of broadening participation work [9] that provides educational design strategies to potentially facilitate bridging the gender gap and for broadening access to young people relates strongly to the findings of the report from the American Association of University of Women [1]. To widen participation the researchers suggest focusing on themes rather than challenges to provide a broader potential of authenticity in engagement for the learner [15]. Essentially, the learner is more likely to engage with an activity if it has meaning/value to the learner. The combination of art and engineering materials provides a further entry point for learners to participate. Encouraging story telling into the activities enables social construction and this role-play activity through a narrative provides a creative setting of externalizing one's thinking to share with others. Again, strengthening the authenticity of learning experience and ownership. Finally, the approach suggests the role of exhibitions rather than competitions being more inclusive. This final feature of presenting in such a setting supports diversity and inclusion and validation/recognition of the learner's contribution [7].

From [13] to [21] educators have argued that the curriculum separation of knowledge from experience requires the teacher to draw the pedagogy of experience into the classroom. Within the classroom, teachers often use a child's informal experience to help with the learning process. However, while schools offer a variety of learning experiences, they are not in a position to easily bridge, benefit or share in the informal learning encounters that children engage with outside school. There is little research to date to support a formal to informal learning framework to scaffold learners in this process [17]. A process of 'instrumentalization' enables the experiential learning to form an active part of formal learning.

Globally, only half of working-age women are in the labour force, and those who work earn a greater less then male counterparts in the same jobs. Transition rates from education to employment are consistently lower for women, contributing to the high level of joblessness. And most troubling of all, women comprise a majority of the 175 million young people globally, who are still illiterate. Although more women graduate form university than men, they remain still a minority in the STEM jobs that will survive into the future with the 4IR. According to the 2016 US census data, only one in seven women with a degree in STEM works in that area. This holds true for most countries. The entrenched inequalities and discriminatory social norms that keep women restricted to low-paid, poor-quality jobs will likely be magnified by the impacts of the 4IR.

That is why we consider the results of the EU project AYEN (Active Youth Entrepreneurship Network), which addresses the issue of NEETs (Not engaged in Education Employment and Training) education, including especially young women. Many young people that nowadays are classified as NEETs have the necessary education and skills to contribute to the development of their societies, but, according to the European Commission, are often disconnected to the demand side (economy). The objective of this project is to build a transnational entrepreneurial network that facilitates NEETs primarily in the age group of 25-29 to see needs/opportunities within their own community that can be developed into new businesses and jobs. Through a comprehensive set of innovative tools, such as a gamification tool, the partners from five Southeastern European countries will use and strengthen existing regional entrepreneurial communities to foster sustainable job creation.

The paper is organised as follow. Section 2 describes the project objectives and Section 3 sketches the solution by adopting the Mobile Twin Peaks approach of Software Engineering. The current State of the Art has been discussed in Section 1. In Section 4 we give a scenario of application of the chatbot concept with the chatbot “mentor-me”. Finally, the Research Methodology and Approach as well as the Originality and innovative aspects of the research programme are addressed in the Conclusions.

2. Objectives and Overview of the Research

Objective 1) Discover and identify the hidden phenomena and reasons for younger women, especially NEETS women, to quit the pursuit of technological greatness during the process of STEM education. To do so, we aim to understand the obstacles in achieving the aspirations of learners in the current STEM education system by ethnographic study (i.e., non-intrusive systematic observations);

Objective 2) Intervene the STEM education with appropriate measures and find recommendations to rectify these trends. To do so, we aim to instrument the current delivery of education inside and outside the school by innovative pedagogy approaches and evaluate the effectiveness of such intervention through engaging activities such as mobile technologies and mobile learning, and role models.

Why GIChatbot?

The more general scope of our investigation is how to design responsible technology for gender equality, i.e. address how technology support inequalities.

Gender bias limit excellence in STEM and therefore reduces the benefits that R&D brings to society.

Women’s needs and preferences are not necessarily considered in research and development, which traditionally has been mainly carried out by men. This can be attributed to several factors, including the lack of gender balance in product design teams and the lack of consideration of gender differences in determining end-user preferences. Efforts to cater to female clientele often focus on superficial adjustments to the exterior design of products, a practice referred to as ‘pinking’. By means of operational guidelines for gender-sensitive innovation, the technology industry can contribute largely to empowering women by developing technology that responds to their everyday needs and preferences.

The issue of gender biases in knowledge production and product design is linked to that of women’s participation in STEM employment and in production processes. Including women as researchers and innovators represents more than a gain in talent and skilled labor: it also leads to the inclusion of the specific types of knowledge women develop and maintain because of gender roles.

In developed countries, the exclusion of women from the design and development of new information technologies (IT) has produced artificial intelligence (AI) with limited capacity. AI has traditionally been modeled on rational-cognitive processes associated with males. More gender sensitive technologies need to be developed such as sociable robots with Ambient Intelligence (AmI) that incorporates ‘social’ and ‘emotional’ learning.

Science and technology research, results, epistemologies, products, and processes are commonly viewed as value neutral. S&T, however, is influenced at least in part by cultural, economic and social factors, and as a result, can be affected by conscious and unconscious gender bias.

For example, in medical research, data arising from studies conducted mainly on males are often extrapolated to both sexes, despite the biological and social differences between women and men.

When drugs are not tested on females, the cost to human life and to business is high. Between 1997 and 2000, ten drugs were withdrawn from the market in the United States because of life-threatening health effects – four of these showed greater severity in women. Preclinical research where testing was done primarily on male animals has been evoked as an explanation.

The challenge is to design technology for women to support engagement, that is:

1.developing a framework where R&D happen based on intelligent chatbot that initiate the discussion to unlock gender bias, and

2. using shared wearable IoT applications for debating and investigating technology for engagement of women and girls in STEM.

GIChatbot Focus

This implies to:

- Promote STEM (Science, Technology, Engineering and Maths) learning by making through collaboration and production
- Adopt a participatory, user-driven approach, rather than a technology-driven approach, in research, knowledge production and technology development that takes gender into account and is tailored to the local context.

- Systematically include gender analysis, and consult with women on design, use and deployment of technologies that support women's needs in all tasks they undertake.
- Undertake gendered situational analysis/assessment and gender analysis of programming and implementation for all Science, Technology, Engineering and Mathematics and Medicine (STEMM)-related actions, policies and programmes.

This example highlights the importance of integrating gender analysis into STEMM research and design. First, including a gender perspective in STEMM development stimulates creativity, enhances scientific knowledge production as well as technological and business innovations, and leads to greater social applicability. Secondly, ignoring a gender framework wastes resources and affects profits. In industrialized countries, women's purchasing power has risen dramatically in recent decades, but products do not necessarily take women's needs or preferences into account. This makes gender-sensitive innovation and a focus on female preferences for technology products an attractive but overlooked business case for many industries.

Thirdly, the use of gender analysis also touches on women's right to health and well-being, which Governments have an obligation to protect and promote. In some sectors, failing to perform gender analysis has serious – and possibly fatal – consequences for women. For example, women are often left out of basic engineering design. Automobile crash test protocols, for example, define short people (mainly women, but many men as well) as 'out-of-position' drivers because they sit too close to the steering wheel. Not all tests adequately consider 'out-of-position' drivers, and this group is more likely to be injured in accidents. Medical research provides another illustration: because of gender bias, adverse drug reactions occur more frequently in women than in men. For example, over-the-counter antihistamines, initially tested in men, can lead to potentially fatal heart arrhythmia in women.

This implies to:

- Train women in using and maintaining ICTs, as well as developing content, applications and software, including free and open-source software.
- Promote the development of content that speaks to women's interests, responsibilities and activities, and ensure its accessibility, including using local languages and audio-visual materials.
- Develop resilience in students learning and engagement in STEM

We want to adopt the approach of learning by making as a medium for students to explore STEM using a constructionist approach with a particular focus on computer science and engineering. The use of IoT as a Technology Enhanced Learning (TEL) tool created the learning conditions to be studied: (a) collaborative: no one person had the knowledge to complete the project alone (b) problem-based: no off the shelf solution was used and (c) multidisciplinary: the learning context pushed the boundaries across the subjects.

The Twin Peaks Approach.

To achieve these two objectives, we will bridge the silos of educators and learners through a mobile communication channel implemented as a chatbot (we call "Mobile Twin Peaks"). It continuously monitors the insights and recommends / suggests progressive actions to take in iterative education processes. Chatbots can help providing individual learning support with limited investment of financial and organizational resources. Chatbots are computer programs used to conduct auditory or textual conversations [20] and are becoming a ubiquitous trend in many fields such as medicine, product and service industry, and education. A growing body of evidence suggests that these programs have the potential to change the way students learn and search for information. Especially in large-scale learning scenarios with more than 100 students per lecturer, chatbots can solve the problem of individual student support. Winkler et Soller [20] pointed out in their systematic literature review that chatbots are in the very beginning of entering education. Few studies suggest the potential of chatbots for improving learning processes and outcomes. Chatbots have a growing presence in modern society, becoming integral parts of everything from personal assistants on mobile devices to technical support help over telephone lines, and even being used for health interventions. In 2015, the size of the chatbot market comprised 113 million U.S. dollar and is projected to be 994.5 million U.S. dollar in 2024.

The original Twin Peaks approach [12] consists of intertwining software requirements and architectures to achieve incremental development and speedy delivery (for the developers) of a solution that fully satisfy the users. The name Twin Peaks emphasises the equal status given to requirements and architectures in this approach to incremental software development, in an iterative process that produces progressively and concurrently more detailed requirements and design specifications. Our Mobile Twin Peaks approach is inherently iterative to support incremental actions in iterative education processes.

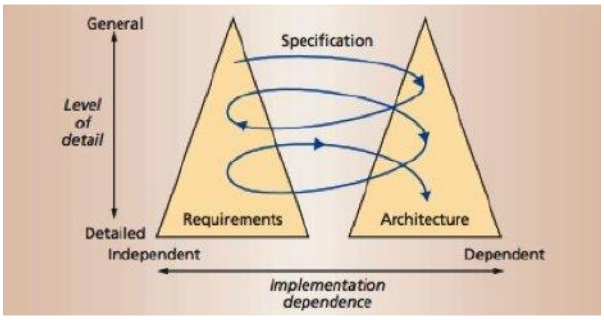

Figure 1- Twin Peaks Approach

There is significant evidence emerging in education that illustrates that knowledge construction supporting authentic learning experiences provides highly engaging and motivating learning experiences for students. However, the evidence is currently fragmented. The trends in maker-community's engagements have provided a number of interesting results. Education research across the sector and domains has illustrated the potential of purposeful/authentic learning experiences. They confirm the findings of Bransford et al (how people learn [7]), Seligman et al (positive education [17]) and Scardamala [15] (knowledge construction) research findings when active pedagogical approaches are used that include the value of diversity/inclusion and can potentially result in resilience. The proposal of work is to jointly developed with teachers and researchers, designers, artists and scientists to build on and create learning experiences to contribute to community-driven international digital living learning hub that is underpinned with investigating the role of diversity through STEM in the context of communities that are physical, virtual and blended in the shared enterprise development of innovation and creativity in applications of health and environment as part of this learning experience. The approach includes diversity and resilience and incorporates the evaluation of learning about STEM through STEM drawing on emerging technologies of Internet of Things (IoT).

Chatbots in education promise to have a significant positive impact on learning success and student satisfaction. However, a small number of studies have already shown successfully implemented chatbots in learning scenarios. A virtual assistant is an example of a chatbot.

A growing body of evidence suggests that these programs have the potential to change the way students learn and search for information. Especially in large-scale learning scenarios with more than 100 students per lecturer, chatbots can solve the problem of individual student support. However, chatbots are in the very beginning of entering education. Few studies suggest the potential of chatbots for improving learning processes and outcomes. Chatbots have a growing presence in modern society, becoming integral parts of everything from personal assistants on mobile devices to technical support help over telephone lines, and even being used for health interventions.

HOW AND WHY MIGHT CHATBOTS HELP US?

The utilization of artificial intelligence (AI) has increased 48 percent of educational activities until the positive impacts of artificial intelligence (AI) are mostly found from the preschool students to university students' different educational levels [3]. To gear in learners' maximum of AI-based education, however, chatbots were all created for different learning devices, and some of them were adapted for personalized tools. A Chatbot (or Chatterbot) is a software (machine) that talks with a user (human): it is a virtual assistant able to answer a few user questions, providing the correct responses. In the last few years there has been a fast growing up of the use of Chatbots in various fields, such as Health Care, Marketing, Educational, Supporting Systems, Cultural Heritage, Entertainment and many others. Major companies have developed several Chatbots both for industrial solutions and for research: some of the most famous are Apple Siri, Microsoft Cortana, Facebook M and IBM Watson. These are just some of the most popular systems[4]. Chatbots have been used to provide a different way of services on many websites since they can help smoothing the human-computer interaction aspect of any automated service at low cost. However, a lot of time and effort are required to prepare conversation. A botmaster must prepare masses of expected questions and answers generally by himself[5]. One of the most challenging research tasks is the development of effective Chatbots: the emulation of human dialogues, in fact, is a really difficult task and involves problems related to the NLP (Natural Language Processing) research field[6]. A Chatbot is an automated computer program which replies to user as it understands input.

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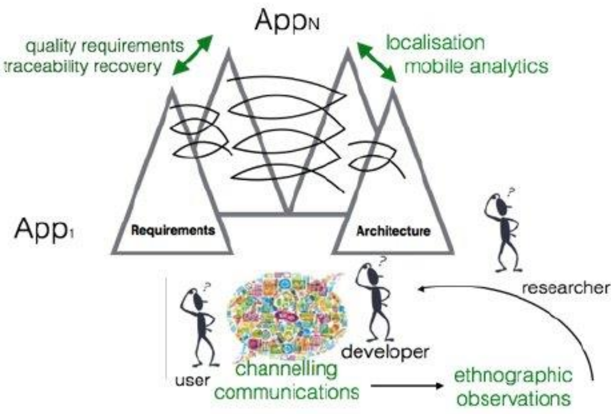

Figure 2 . Twin Peaks Approach to develop Apps in Software Engineering [4]

We also highlight how the novelty of the project is in making use of **ethnography** to understand the learner's behaviour and of mobile learning to stimulate the young girls to study the STEM disciplines. We aim to demonstrate as in Gendered Innovation how do sexes engage differently with the obstacles to study STEM disciplines. Is there a way we bring in a gendered dimension to this project and provide an innovative more nuanced insight to the proposed research objectives.

3. Scenario

For example, in an illustrative scenario, Julie has on her mobile platform (e.g. a tablet device) an App that contains the "mentor-me" education service chatbot. Julie's school hosts this service to provide access to Julie's current curriculum activities. One of these is to explore microclimates at the school, an activity supported by the nQuire project (http://www.nquire.org.uk/). The "mentor-me" is an application supported by mentoring services. One of Julie's buddies posts a question about how to reduce water usage under the 'conserving water' topic. The "mentor-me" matches the topic with the microclimate project they are doing at school, automatically tagging the query. Julie posts a suggestion about collecting any cold water thrown away from the warm water tap into a bucket to be used for plants in the home. The "mentor-me" tags this response providing a link to common household high water usage appliances from the school curriculum site. Julie is asked questions from the chatbot about how water conservation relates to her microclimate project. Mentors such as family comments are added through an interview panel. Julie's dad explains that they use native plants in the garden because they work well with the climate and demand less water and fertilizer to grow. Julie adds this and sends it back to school. The "mentor-me" has a follow option, when Julie passes a recycling point the "mentor-me" chatbot alerts Julie. An interactive artefact is provided for Julie to browse. Julie is asked to add her comments about how important recycling is and how this impacts the microclimate. In an interview panel, Julie can select a question for her teacher to ask about recycling glass and plastics. As Julie investigates today's weather "mentor-me" chatbot provides related weather information that links to microclimates and a geography project she is working on. Julie's inputs are added to the shared school repository service for the teacher to view. The teacher can browse activities or use them when preparing the plan e.g. for investigating the development of microclimates or thinking about teaching innovations. The mentor, here played by the teacher, decides which content to bring into focus and share with other children, based on the curriculum, while the student provides her experience related to the knowledge. Knowledge is co-evolving between the students and the teacher, expanding the knowledge of the system by adding the new knowledge shared between students and teachers that can then be used further. This makes the projects authentic to the learner.

4. Conclusions

Our project builds on some key methodology principles to enable a transformation of engagement for girls in science:

(1) Design thinking, using co-design approach, that drives empathy-based participation into the design and development the digital living mentoring and learning hub focusing on health and environment applications.
(2) Enabling and supporting informal learning activities to be linked to formal learning experiences, enabling learning to be learner centric. This results in empowerment through authentic experiences.
(3) Mentoring engagement that enables through co-design and 'maker community practices' a shared respect and mentoring exchange to develop self and community value.

Through the digital living mentoring and learning hub and outreach activities and community driven access through applications of health and environment as the starting focus. However, as the learning hub develops, we expect this to driven by the co-designers.

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