

RESEARCH ARTICLE

Heroine's Learning Journey: Motivating Women in STEM Online Courses Through the Power of a Narrative

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ABSTRACT Although Science, Technology, Engineering, and Mathematics (STEM) are essential for the development of society, men hugely outnumber women in the majority of STEM fields in higher education, a factor that hinders inclusion and restricts the possibility of having different points-of-view. Previous studies indicate multiple causes of low female motivation in STEM degrees and careers, which inspired several initiatives to increase female interest in STEM. A proven way to captivate an audience to change its attitude is the heroic narrative model, a style of narrative in which a character goes through a sequence of difficulty-increasing and attitude-shaping quests. This paper proposes a heroic narrative model named Heroine's Learning Journey (HLJ) targeted at counteracting low female participation in STEM courses. In particular, the HLJ model is developed especially for enhancing STEM online courses, by using a narrative that can encourage female students to engage and prevail in them. The HLJ model is divided into three acts, each composed of several stages symbolizing steps tailored to a female student's development. The model was applied to set up the structure of a preexisting Machine Learning online course with hundreds of enrolled students. Although a first version of the course already presented a higher-than-expected female enrollment *per se* ($\approx 37.3\%$), with HLJ, we verified an even higher female enrollment ($\approx 59.2\%$), slightly surpassing male enrollments. The feedback provided in learners' responses to a final, voluntary and anonymous questionnaire, allowed to obtain the degree of satisfaction of participants at the end of the course with the HLJ. The responses indicated that, at the end of the second edition of the online course, students were able to acknowledge the existence of a STEM gender imbalance, and appreciated the motivating nature of the HLJ model. From several student's feedback and comments submitted in the questionnaire, one can conclude that the attitude-shaping character of the HLJ was greatly appreciated, in addition to the technical content of the course. All these preliminary results are indicative of the usability of HLJ to foster gender balance in STEM online courses. Thus, the present study contributes to STEM Education by leveraging the motivation of young women to enter and prevail in these areas of study.

INDEX TERMS Narrative, gender equality, motivation, STEM.

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I. INTRODUCTION

Nowadays, even though STEM (Science, Technology, Engineering, and Mathematics) education and careers leverage

the technological development of society, it still faces a deficit of female participation, which we believe jeopardizes a culture of inclusion where diverse points of view are taken into account. Achieving gender balance in STEM education and careers is therefore an important aspect to guarantee a brighter future of human society at large [1]. Research suggests that this trend may be caused by several factors before and upon female enrollment in Engineering and Science degrees, such as a lack of knowledge what an Engineering career is about, a lack of self-confidence on their abilities to work in STEM, the invisibility of female role models, and societal gender stereotypes about intellectual (Mathematics) ability [2]. The present work aims to foster female enrollments and active female participation in STEM education by introducing the Heroine's Learning Journey (HLJ), a model applied to enhance (online) courses based on the premise that heroic journeys [3], [4], [5] can encourage female students to engage in STEM education. The choice of applying the HLJ to STEM online courses, notably STEM MOOCs (Massive Open Online Courses), is a natural consequence of the Fostering Women to STEM MOOCs (FOSTWOM) Erasmus+ project [6], in which some of the authors were involved [7].

A major goal of the HLJ is to support young female students, aged between 15 and 21 years old, an important age range for taking career decisions, in having a positive experience while enrolled in a STEM MOOC. That is, to ensure the possibility of young girls to boost their self-esteem and confidence to work in STEM, being motivated to pursue STEM studies and/or a STEM career, while improving their skills on mathematics, programming and/or engineering modeling [8], [9].

Another contribution of this work, complementary to the HLJ, is the development of Heroine's Learning System (HeLaS), a web application developed to integrate the model into an existing learning support system. HeLaS allowed us to test the applicability and relevance of the HLJ when integrated with a preexisting Machine Learning online course, targeted to an audience mainly of Brazilian and Portuguese young students.

Overall, this document is laid out as follows: we start by reviewing the challenges regarding female participation in STEM courses, as well as several initiatives that can help to mitigate this imbalance (section II); next, we describe different versions of heroic narratives, and how these can be translated to a student's learning journey (section III); afterwards, we demonstrate our model named Heroine's Learning Journey (HLJ), describing its strategy, the roles involved, and its narrative (section IV); finally, we present and discuss the application of HLJ to an online course through HeLaS, extracting some insights to improve the model and to guide future research directions (sections V, VII and VIII).

II. WOMEN PARTICIPATION IN STEM

Gender inequality in society, and particularly in education, is not a new phenomenon, and steps to mitigate it are still

being taken. In fact, gender equality and women empowerment constitutes the fifth of the United Nations Sustainable Development Goals (SDG), being described as transversal to all of the other goals, including "Quality Education" [10]. Regulations are still needed to avoid discrimination based on sex or gender, e.g. Brazil and Portugal recognized the need for regulation by including specific gender equality provisions in their constitutions [11], [12]. Although many countries implement gender-equality measures, some imbalances are still verified, e.g. a majority of younger women have a tertiary degree [13], a trend which delays women's participation in STEM fields.

A. THE CURRENT STATE OF FEMALE PARTICIPATION IN STEM COURSES

Women are underrepresented in STEM higher education degrees. According to UNESCO, they represent only 35% of all students enrolled in STEM-related fields of study [14], even though this percentage varies greatly from country to country [13], [15]. Among undergraduate STEM students, young women are much less likely than their male counterparts to state that they are interested in pursuing a graduation or a career in STEM [16], [17], [18], [19]. However, O'Dea et al. argue that, in average, women outperform men in STEM, although by a smaller difference than in non-STEM areas, and also have more consistent grades. Even so, they have less representation among top-performing students [20].

Engineering is often a challenging undergraduate degree program. As a result of different cultural, educational, and technological issues, such as curricular overload, time disputes with leisure activities, personal insecurity, lack of self-confidence and traditional teacher-centered learning methods, its undergraduates face difficulties both to enter university and in finishing their bachelor degrees [21], [22], [23]. Particularly, the same research shows that female students face an exacerbation of these challenges while pursuing an Engineering degree. This factor is associated to the Research Agenda for Engineering Education [24], where one can find the concern to achieve and sustain a diverse engineering community. Even so, these challenges are not exclusive to Engineering education, being broadly perceived in most areas of STEM [14]. This fact motivates many researchers and organizations to try to understand the reasons and possible solutions to balance female participation in STEM degree programs [14], [25], [26], [27], [28].

B. CAUSES OF LOW FEMALE PARTICIPATION IN STEM AREAS

Both qualitative [21], [22] and quantitative [14], [15], [27], [29] studies have shown strong evidence that stereotypes and lack of confidence can negatively influence female experience and academic gains while participating in STEM areas. Most studies on this matter focus on K-12 education [17], [30] and undergraduate degrees [15], [23], however some also identify the same negative influence in career

development [19], [31], [32], as well as graduate degree programs [33]. In fact, Blackburn [2] made a thematic review on this subject, finding several aspects that hinder successful females' degree completion and career entry, e.g. stereotypes, biases, chilly campus cultures, and unsteady identities [2].

Being held back by discrimination, biases, social norms and expectations that sometimes influence the quality of education they receive, young women are negatively influenced to choose and prevail in STEM higher education. Saujani [34] defends that men are stimulated to be courageous and face any challenge, while women are taught to avoid risks and failures, seeking perfection. According to the author, the consequent low level of courage (or self-confidence) is one of the reasons why women are underrepresented in STEM. One example of this behavior is described by Mohr [35]: "Men apply for a job if they meet just over half of the qualifications, while women will only apply if they meet all qualifications". Even so, Saujani [36] proposes that "When girls are taught to be brave, and have access to a support network, they become braver" [36]. In fact, the factors explained above can be coupled to a lack of clarity about what STEM represents and how to benefit from academic support, professors and colleagues in the field [22], [37]. This is corroborated by Cruz and Kellam [37] who have compared the experience of 21 undergraduate students, 14 male and 7 female, about their contact with Engineering, and identified the presence of erroneous "conflicting interests," which can be attributed to misinformation or to poor knowledge. For instance, one of the interviewed female students said that she almost sought journalism because of her need to be creative; and another one, also female, believed that engineering would not provide her the creative outlet she needed. Meiksins and colleagues [38] also point out that a better balance is needed between academic research and practical engineering research, for instance by the provision of more friendly workplaces for studying and working.

In our opinion, comments like these may suggest that, in general, the social and creative aspects in engineering projects may still be under-disseminated, which may in turn lead to a misinterpretation of what the STEM fields are about, and have a particularly negative effect on female motivation.

Another factor suggested to have a negative impact in female motivation towards STEM is the lack of their exposition to female role models [39]. For instance, Chen et al. verified that the early high school teacher's gender and their gender matching with students positively influenced the science identity of students in some STEM fields (that students thought of themselves as related to science), a factor which was particularly relevant for female students [40]. In fact, additional research argues that the inclusion of role models in the form of successful teachers and tutors [41] is able to bolster female academic performance and persistence in STEM degrees. Other factors suggested to positively relate to the development of student STEM identity include early (elementary school) teacher encouragement in STEM and having positive K-4 science experiences [42]. Upon this

reflection, even though we identified a plethora of possible causes for low female participation in STEM degrees, one aspect still lacks exploration: *How can this effect be mitigated to help proliferate a more inclusive and diverse culture among STEM students?* We will focus in finding some answers in the next section.

C. INITIATIVES THAT SEEK TO INCREASE FEMALE INTEREST IN STEM

To help understand how to increase STEM female participation, we will draw from gender-balance initiatives [43], some of them triggered by the interest of higher education institutions in increasing the number of female students and raising their retention rates in STEM degrees [22]. Multiple different initiatives foster the participation of girls and women in the areas of STEM [44], [45], notably in Brazil [46]. Some examples of these initiatives include International Gender Champions [47] and PyLadies [48]. One way of reaching a broad audience is through media or STEM-oriented products. For instance, Cohen et al. demonstrated that K-4 elementary school students experience with STEM-related toys/kits, TV programs/movies, or computer/video games, translates to STEM identity capital, i.e. a positive effect on STEM identity is present longitudinally, from elementary school to early college [42]. Even so, the authors also verified that female students were less involved in three of the five positive predictors of STEM identity (playing STEM computer/video games, using STEM toys/kits, and watching STEM-related TV programs or movies), thus inherently having a decreased chance for identity construction and subsequent persistence in STEM. Nonetheless, the awareness of how media can motivate females towards STEM led many recent works to acknowledge the role of women in STEM, sometimes using widely known profiles like Marie Curie and Lady Ada Lovelace, and other times less known female personalities with important contributions to Science, Engineering and/or Mathematics [49], [50], [51]. One relatively recent example of dissemination of the positive work done by female African-American mathematicians and engineers at NASA with worldwide repercussion, is the movie *Hidden Figures* [52], loosely based on the non-fiction book with the same name [53].

The gender-balance initiative was also leveraged by the *STEM and Gender Advancement (SAGA)* project to "support gender equality in Science, Technology and Innovation (STI)" [54]. This project has published *The SAGA Science, Technology and Innovation Gender Objectives (STI GOL)*, from which the first is to "Change perceptions, attitudes, behaviours, social norms and stereotypes toward women in STEM society" and the seventh is to "Promote gender equality in science and technology-based entrepreneurship and innovation activities" [55]. Another initiative is the *Athena Swan Charter*, which aims "to support and transform gender equality within higher education and research"

through the creation of guides that can provide knowledge about the demographic diversity of a population [56].

The FOSTWOM (2019-2022) Erasmus+ project, has provided guidelines to use the open and innovative format of MOOCs to produce more inclusive STEM educational content. Within the scope of FOSTWOM, two MOOCs for undergraduate and graduate students in STEM were created [6], [7]. One of these MOOCs, the “Machine Learning, Maths and Ethics: Hands-on” that provides academic content free of gender stereotypes about intellectual ability, will be analyzed in more detail in the section V-A. It is important to notice that females usually comprised circa 20% of active enrollments and had a completion rate 30% lower than their male peers in STEM MOOCs [57].

Based on primary data (survey inquiring the registration of an initiative) and secondary data (authors' search), Costa et al. investigated current initiatives to promote gender equality in STEM education in Brazil, comparing them with initiatives found in other countries [25]. After analyzing whether these initiatives aligned to the Brazilians' gender equality needs, 30 were identified, and found to be contributing in some way to the aforementioned objectives of SAGA. In fact, almost all of them support some type of STEM training for women, and involve the creation and promotion of technological centers and centers of excellence or communities, although only two ultimately offer scholarships to leverage female participation. This study is particularly relevant for the present research, given that we will focus the application of our model in a MOOC adapted for reaching a young Brazilian audience.

Overall, referring to the challenges for female participation in STEM degrees, we can conclude that: (i) there is a considerable difference in the participation of female and male students in STEM; (ii) there is a large body of evidence about specific factors that may diminish women participation in STEM, which often relate to or originate in a lack of motivation for entering or continuing the STEM studies; and (iii) this difference is recognized by the society, which aims to reduce it through a myriad of initiatives.

III. FOSTERING MOTIVATION

Because of the revealed importance of woman motivation in their choice and participation in STEM, in this section, we review the role of motivation in the education process, and in particular, how the Self-Determination Theory (SDT) can be important to encourage the progress of students' skills.

According to Deci and Ryan [58], the motivation construct can be divided into extrinsic and intrinsic motivation, whether the drive an individual has to behave in a certain way is based on external sources as rewards, or comes from within the individual, i.e. their core values, interests, or personal sense of morality [58]. Ryan and Deci further introduced the SDT [59], which defends that, intrinsic motivation may arise from the satisfaction of three basic needs: competence, autonomy, and relatedness [59]. Some authors defend the importance of goals and their positive relationship with student performance within the context of education [60],

[61], [62], [63]. Research suggests that intrinsic motivation is the most important form of motivation in high school performance [64], [65], with additional positive results in higher education [66], [67], STEM higher education [68], [69], and more specifically in STEM higher education for young women [70], [71].

A. THE POWER OF A NARRATIVE

Several authors defend the flexibility and the power of a narrative to convey information and share experience [72], and in particular its value to improve learning [73], [74], [75], [76]. Narratives consist in the representation of a story, using events interconnected through time [77], [78]. Usually, narratives tend to follow a structure targeted to display different emotions and vary spectator tension throughout the course of the story, making it more interesting. This structure was conceptualized in ancient times, in Greece [79] by the philosopher Aristotle, who proposed the division of a narrative into three acts: Configuration, Conflict, and Resolution [80], [81], a notion which has been studied and refined over time. Recently, Digital Storytelling, i.e. the use of media to tell a story through a narrative, has become a powerful instructional tool for both students and educators [72], [82], [83], [84]. A good story, told through a motivating narrative and incorporating image, sounds, and videos [83], [84], can hold individuals' attention, notably students, and take them on a journey, evoking emotions, intentions, and ultimately provoking a transformation, and even inspiring the choice of a professional path. Beyond education, Madsen et al. [85] presented emerging narratives based on game design theory as an application model in the cultural area, allowing a discussion on how the criteria of emerging narratives can support exploratory behavior for their users [85].

The narratives of great personalities can transform our way of thinking, making us reflect and acquire self-determination [86]. Using the story of Emperor Hadrian as an example, the author affirms that “our life stories' narratives are related to our emotional state, our interpersonal and social relationships.” In fact, there is evidence that identification with a fictional character can lead to changes in the beliefs, attitudes, and behavior of individuals [87]. Broom et al found evidence that “when people identify with a story's character, they are influenced to assume some of his or her characteristics” [88]. They also found that the more people are immersed in the narrative, the more they tend to “become” the fictional character, using the part of the brain responsible for thinking about themselves. For example, many educators have reported that they felt inspired by fictional characters, such as Robin Williams' character John Keating in “Dead Poets Society” [89], and that this changed the way they view the educational process. Aligned with our premises, several women reported being influenced to pursue a career in the health area, due to the fictional role model of Meredith Grey, played by actress Ellen Pompeo in

the *Grey’s Anatomy* [90] television series. Another important fictional female character who influenced women was Scully, from the *X-Files* television series. A systematic study on the influence of this last fictional character on girls and women was labeled “the Scully Effect” [91]. This connects to the already mentioned positive impact of female role models in motivating women to follow a STEM career [92], [93]. In particular, research suggests that reading biographies of successful women in STEM fields improves women’s perceptions about those fields [94] and also helps women persist in STEM degrees [41]. In fact, implicit gender-STEM associations can significantly impact women’s tendency to pursue careers in STEM and how they value those fields, regardless of their STEM identity [95], [96].

1) HEROIC JOURNEY NARRATIVES

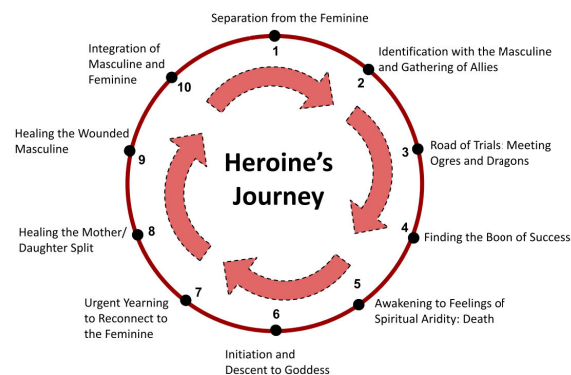
Throughout history, several distinct narrative models have focused on the self-improvement journey of a heroic character [3], [5]. These models were based on analytical psychology backgrounds, and present similar characteristics. Even so, we find it relevant to broadly define how a heroic journey narrative should be presented and structured, as we felt the need for a general ontology on this regard. In our opinion, a heroic journey is a style of narrative in which a character, or a party, goes through a sequence of quests, usually increasing in difficulty, which act as a preparation for a final challenge, that can only be overcome by those who are well-prepared. In doing so, through rules, acts, stages and transformations, there is a motivational change in the way of how the main character understands the challenge. The aspiring Heroic character seeks self-awareness, which includes recognition of their abilities, and to face and overcome various obstacles in order to defeat the final, epic challenge. Throughout their journey, the Heroic character usually needs to rely on the assistance provided by allies. After overcoming the final challenge, the character is transformed by the experience and acquired learning while completing the journey, and is prepared to help others in their own journeys and transcendence.

One line of research that inspired the construction of multiple narrative structures is Carl Jung’s characterization of archetypes. His studies of archetypes took into account the myths that occur “practically all over the earth” [97], producing, among others, four important archetypes: the Persona, that is the desirable image of ourselves to others that functions as a mask, e.g. a teacher or student; the Shadow, i.e. everything that we deny in ourselves and cast into oblivion, for example dark thoughts and moods for which we feel guilt and shame; the Anima or Animus, i.e. the archetype that expresses the unconscious feminine side of a man (Anima) or the unconscious masculine side of a woman (Animus); and the Self, i.e. the archetype of wholeness, what Jung called ‘I’, the most significant of all archetypes, which was derived from models of people, and the behavior or personalities, e.g. Ruler, Creator/Artist, Sage, Innocent, Explorer, Rebel, Hero,

Wizard, Jester, Everyman, Lover, or Caregiver. In addition to the examples above, we can also mention the Mentor and the Ally as archetypes that can help the hero, as well as the Great Mother/Mother/Feminine archetype [98], [99], [100]. Inspired by this categorization, narratives structured as journeys were built to influence and inspire different audiences, e.g. the monomyth concept of the Hero’s Journey by Joseph Campbell, described for the first time in his book originally written in 1949, which has some subsequent editions [3].



(a) Hero’s Journey by Campbell. Adapted from [3].



(b) Heroine’s Journey by Murdock. Adapted from [5].

FIGURE 1. Depiction of the Campbell (a) and Murdock (b) heroic journeys.

Joseph Campbell proposed the notion of the Hero’s Journey narrative [3], which was adapted by Vogler [4] and broadly adopted by the movie industry. The Hero’s Journey, notably Vogler’s adaptation [4], had a strong influence on novel and script writers for many years [4], [101]. Similar to Jung’s notion of archetypes and universal mythology [99], Joseph Campbell defined the archetype of the Hero, embodied in the myths and legends of many cultures, from which Homer’s *The Iliad* is a classical example [101]. The Hero’s Journey has three acts. It starts with the *Departure*, goes through *Initiation*, and ends with the *Return* [3]. These acts are further divided into 17 stages, as depicted in Figure 1. The hero’s main motivation is not

solely driven by external rewards or recognition but by an inherent need to align their actions with their core values and/or aspirations. The process of transforming the common man into a hero, according to Campbell, is mainly based on intrinsic motivation. Intrinsic motivation, which refers to the internal drive and satisfaction derived from engaging in an activity for its own sake, can be connected to the hero's journey in several ways. Firstly, the hero's journey begins with a call to adventure, where the protagonist is driven by an inner desire or curiosity to embark on a challenging quest. This initial motivation arises from within the hero, highlighting the intrinsic nature of their motivation to explore, learn, or achieve something meaningful. Secondly, as the hero progresses through the stages of the journey, they encounter numerous obstacles, setbacks, and trials. It is their intrinsic motivation, their deep-rooted sense of purpose or determination, that fuels their perseverance and resilience in the face of adversity. The hero's internal drive to overcome challenges and achieve their goals serves as a powerful intrinsic motivator throughout their journey. Furthermore, the hero's transformation is tied to their intrinsic motivation. As they navigate through the journey and confront various trials, the hero undergoes personal growth, self-discovery, and development. This transformation is driven by their intrinsic motivation to evolve, overcome limitations, and fulfill their potential. Lastly, the hero's journey involves the pursuit of noble ideals or the fulfillment of a higher purpose.

The Hero's Journey conceived by Campbell is defined as an internal cyclical and spiritual journey for every person: there is an initial reluctance to the challenge of becoming a Hero, but such an endeavor culminates with the final form of the character who must help the world: Lord of two worlds. Even though Campbell [3] writes that "The hero, therefore, is the man or woman who has been able to battle past his personal and local historical limitations..." [3, pg. 14] and Vogler [4] describe the hero as a "person" [4, pg. 30], some considered his narratives to be biased toward a male character [5]. In particular, Maureen Murdock, a psychotherapist practitioner of Jungian analysis, cites Campbell's statement about the no need of a woman-undertake journey: "Women don't need to make the journey. In the whole mythological tradition the woman is there. All she has to do is to realize that she's the place that people are trying to get to" [5].

We must take into account the fact that not only Campbell studied old myths based in ancient culture gender roles, but he also lived in a different era, and both of these aspects reflect the style of narrative found on his book "The Hero with a Thousand Faces" (1949). Back then, the perceived roles of women in society was different, and as such, in most of his studied myths, men and women played more stereotypical roles. In stories based on Campbell's narrative, the hero goes through adversities such as physical challenges to meet women who are either seen as pure (hero's consort) or as impure (temptation). Those roles can hardly be gender reversed, i.e., a heroine tempted or allied with a male

counterpart. These characteristics were the major reason that motivated Maureen Murdock to create the Heroine's Journey, stating that "women do have a quest in this time in our culture" [5]. Maureen Murdock created the Heroine's Journey aiming to describe the experiences of women, supported by her own experience and her conversations with other women, including therapy patients. Her journey has a focus on female spiritual development, aiming to heal what she sees as the internal division between women in a patriarchal society [5]. According to Murdock, the path of a Heroine is a continuous cycle of Development, Growth and Learning, divided into 10 stages (see Figure 1b). The Heroine's Journey follows the general structure of Campbell's mythic journey. Overall, the first part of the Heroine's Journey is about her power and mental transformation. It begins with the step "Separation from the feminine" and an identification with recognition and success based on patriarchal culture, which will later make her experience spiritual death, and return to the inner world with the intention of recovering the power and the spirit of the sacred feminine [5]. The next step is "Road of Trials" which concerns the development of the ego. The second part is about the heroine's outcomes. According to Murdock [5], the heroine needs to work on self-reflection tasks to individualize herself from her parents and to establish her own identity in the outside world. During this process of individualization, the heroine must overcome feelings of emptiness, oppression and inner strangeness, until a recognition of the union and the power of its dual nature for the benefit of humanity. Although in her life story she has helped many women to overcome their limitations and feelings of low self-esteem, Murdock's proposal [5] has some limitations, in part due to the context in which she lived and worked. Reading her book, one can see the notions of self-help and female intuition, which can be quite controversial for Science. Her vision of the world and the consequent creation of the journey, may render less compatible with vulnerable women, of other ages, race and different cultural experiences. Subsequent publications, for example by Valerie Frankel and Victoria Schmidt, underlined the fact that Heroine's Journey "has always existed in epic myths and legends, although it has often been underestimated" [102], [103]. Currently, one can find several other adaptations and discussions regarding female journeys [104], [105], [106].

IV. HEROINE'S LEARNING JOURNEY

In the previous sections, we detailed how the heroic journey narratives of Campbell and Murdock use stages and challenges in order to transform the inner self of a person. Even though these journeys have some aspects in common, each of them presents different characteristics, targeting a specific gender or age range, and reflecting the personal, professional, and social influences experienced by their creators. Inspired by the heroic journey idea, our main goal is to design a heroic narrative targeted at young female students in STEM, taking into account that learning involves complex relationships with several stakeholders, like

teachers, classmates, and academic staff. Thus, we were led to attribute an important role to tutors and/or mentors in the learning journey. Moreover, based on the findings of the previous sections, we also deem that a female student's journey in STEM requires self-awareness and courage, not only for acquiring some specific scientific knowledge, but also for embracing an inner personal growth.

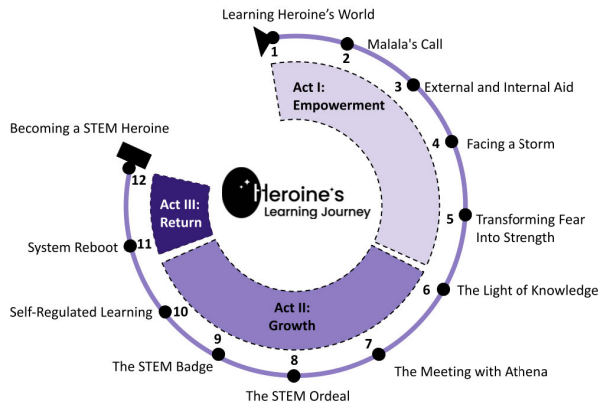


FIGURE 2. Depiction of the Heroine's Learning Journey stages.

As such, in this work we propose the Heroine's Learning Journey (HLJ), a model that uses the power of narrative to mitigate the internal struggles of female students in STEM, while they try to overcome their own fears and the challenges present in a STEM educational environment. It follows the traditional three acts structure [107], and encompasses twelve stages (see Figure 2). For each HLJ stage, we define the corresponding **Narrative**, **Mission**, **Challenge**, and **Assistance** (see Tables 1 to 3).

The model targets young female students, aged between 15 and 21 years old, wondering about their study and career options. We aim to motivate them to actively participate in STEM courses and to dedicate themselves to a career in STEM. This is done by incrementally fostering new skills and knowledge, while presenting inspirational female role models. Such role models are intended to grow self-confidence and self-regulation in female students, through the relatedness they may foster. Because of their wide application as motivational tools in education, we endowed our narrative with central conflict encounters with fictional characters, within a background of mystery stories [108], [109]. Multiple moments of feedback are also included to strengthen the students' level of confidence and improve their motivation [59], [110], [111], [112]. The model was designed with an epic setting in mind, in order to foster intrinsic motivation [113].

We want to notice that despite the fact that the target group of the HLJ model is young female students, we aimed to apply it in an accessible and inclusive way through MOOCs, or other open educational resources. Furthermore, even if we have tried to clearly identify and adequately addressed

specific needs of the target group, we hope that all those whether because of their gender, sexuality, race, ability, class or geographic location, experience unequal treatment or biases in accessing and attending STEM education, can also benefit from the model.

A. ROLES OF THE HEROINE'S LEARNING JOURNEY

The model HLJ divides its actors into different roles inspired by the archetypes usually included in heroic narratives [3], [5], [99]. The following roles are part of the Heroine's Learning Journey (see Figure 3):

- **Learner** is the protagonist of the story, and drives the narrative (relates to Jung's Self, Campbell's Hero, and Murdock's Woman);
- **Learner Heroine** is a former Learner who became a Heroine for having successfully completed the entire journey on a previous execution of the course, and returns as an ally in the current edition of the course to help other students, directly interacting with new Learners. If this is not possible, the Learner Heroine can be substituted by supportive and motivational messages attributed to fictional or real people (relates to Campbell's Lord of Two Worlds and Murdock's Spiritual Warrior);
- **Tutor** provides assistance and mentoring and is fully dedicated to students on a given subject and/or on how they can acquire new skills. The Tutor is selected at the design phase, e.g. by one element of the staff of the course (related to Jung's and Campbell's Mentor);
- **Ally** who is available to assist the Learner in different moments of their journey. This role may be fulfilled by a peer heroine on her own personal quest, experts in a certain subject, a Learner Heroine, or other supportive person. Allies are chosen by the Learner, whenever needed or wanted during the journey (related to Jung's and Campbell's Ally);
- **Mother Goddess** is a fictional character that announces the journey and sets the epic into motion. Can often be replaced by an event, such as an invitation or announcement (related to Jung's and Murdock's Great Mother, and Campbell's Herald);
- **Athena** is a fictional character that assists the Learner in their journey. Provides fundamental knowledge for the heroine's success. Athena enters in stage 9: "The Meeting with Athena" and is a representation of sharing knowledge and a source of wisdom. All the information that comes from this character is always reliable, relevant, and from a direct source of knowledge in the domain of study (related to Jung's Feminine and Campbell's Goddess).

We understand that creating an antagonist character could enrich the narrative, however it would have the side effect of enabling undesirable associations with real life people, such as a specific tutor. Therefore, there is no such character in the HLJ narrative. Even so, Nature is used as a challenge in some stages. Additionally, not all roles here proposed need to be

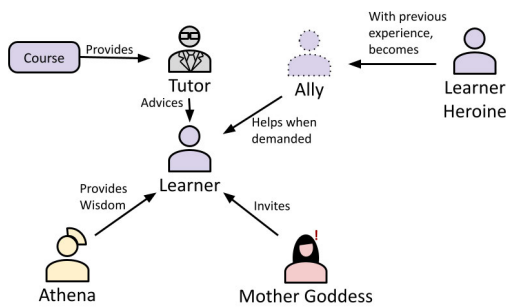


FIGURE 3. The roles present in HLJ.

played by different people, or even by a human being. While applying the learning journey to a given STEM online course, it is possible that instead of a tutor we are able to deploy a chat-bot to deliver the messages and answer the questions. Virtual characters can also be added to the allies category. People external to the course may also be invited to play the role of allies. Those who are experts on the STEM subject of the course, can participate in extra activities, create student support groups, carrying out some practical or theoretical activities.

Besides the aforementioned roles internal to the model, for the implementation of HLJ, there is also the need of several support staff individuals who are not part of the narrative, but who create and manage a course where HLJ is applied. Those parties are:

- **Journey Designer** who is responsible for supporting tutors, for defining which roles will be played by whom, as well as creating a course map, elaborating rules, tutorials, and additional resources. Essentially, this person is responsible for associating the topics of the course with the stages and content of the HLJ;
- **Teacher** who is the content author of the course (e.g. producing the videos, defining the course structure, creating the assessment activities), and facilitates the Journey Designer with information necessary for the HLJ course integration. Eventually, the Teacher and Journey Designer can be performed by the same person.

B. THE NARRATIVE OF THE HEROINE'S LEARNING JOURNEY

The narrative of the Heroine's Learning Journey is constituted by 3 main acts, further divided into 12 stages (see Figure 2):

- **Act I – Empowerment (Stages 1–5, see Table 1)** In the first act, the Learner must accept the change from the common world: the current status of their beliefs; to a new world, that will bring new knowledge and life perspectives. Motivation strategies at this act aim to increase confidence, and to transform fear into strength. As a result of Act I, an empowered Learner should surface;
- **Act II – Growth (Stages 6–10, see Table 2)** The second act consists in skill acquisition. If necessary, the Learner must recognize and find allies to overcome different tests and trials. During Act II, the Learner grows to a new

and better version of themselves. If necessary, stages 4, 6, 8, and 9 can be repeated to allow for better course organization, for example to support subtopics or longer syllabus;

- **Act III – Return (Stages 11 and 12, see Table 3)** The third act is characterized by the final change, transformation, and recognition of Learners into true Heroines, who will then help other Learners on their own journeys. As a result of Act III, there is the Heroine's Return to assist other young women. Some courses may choose not to use the student as a Learner Heroine in a future edition. However, it is important to include a moment in which the Learners can reflect on their learning. For instance, stages 11 and 12 can be implemented by requesting a learning report, in which the learner contemplates what they learned, and what happened throughout their journey.

After defining the acts and stages that constitute the Heroine's Learning Journey, a short video was produced for each stage with a script reproducing the descriptions we provided above. Using visually appealing language and an audio speech with simple and inclusive phrases, these videos are a relevant materialization of the model. In a workshop held in the context of FOSTWOM project, we used the twelve descriptive videos of the HLJ stages to obtain feedback from 12 scholars with experience in different STEM areas (see the demographic profile of the participants, Table 4). For each step, we asked the participants to rate, using a 5-point Likert scale from "Completely Agree" to "Completely Disagree," the importance of the step to motivate a female audience: "I believe this stage of the HLJ is important for motivating young women to participate in a STEM course," as well as the need for improving such a stage: "I believe that this stage of the HLJ needs to be improved to achieve the objective of motivating women to participate in a STEM course." At the end, we also asked participants to rate, in the same scale, the overall value of HLJ to motivate a female audience: "I believe that the HLJ, as a whole, has great potential to motivate women to participate in a STEM course." As suggested by the responses (see Figure 4), the experts found all narrative steps relevant for motivating a female audience, with most positive points at steps 1, 5, and 12, a trend which was corroborated by the ratings given to the last statement ($M \approx 3.7$, $SD \approx 0.78$). The ratings given to the second statement revealed that the scholars felt a need for improving some stages, mainly stages 1, 2, 3, and 6.

As a means to justify the ratings, for each stage, we also asked the participants to assess what they liked about the particular stage (i.e. based on what was illustrated in-video), as well as to describe some ideas they found could improve that stage. Based on the responses, we perceived that participants in the workshop liked the dynamics of the videos and how they could relate to the content, e.g. about stage 2: "I really like the video because it makes [me] believe in myself and make me believe that I can [have] success as well in a STEM field" and "It has good rhythm and timing

and contains inspirational words,” and from stage 10: “I like to understand how the feeling of fear is a ‘normal feeling’: it helps me to start reflecting on that feeling and on how to overcome it.” Even so, multiple answers regarding aspects to improve pointed the clarity of messages and learning path (mainly in stages 1–4 and 12, e.g. in stages 1 and 2: “[I] wish the video explained better her story,” in step 6: “I wish the message was clearer. I had no clear understanding of the message of this video...,” and in step 3: “I wish the self knowledge path was clearer (examples, tools, ...)”). The latter comments were used to further develop the narrative of HLJ, and its translation to the easily deployed video media. In general, the positive feedback given by these experts reflected the practical value of our narrative, by which we continued to believe in its application in a practical scenario, an aspect that will be approached in the next section.

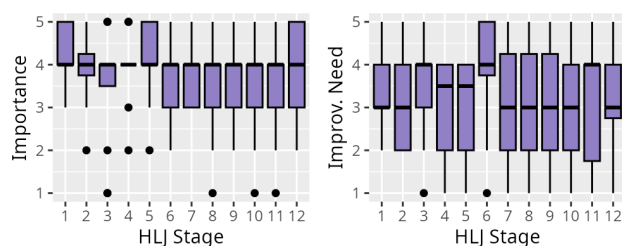


FIGURE 4. Expert feedback on each HLJ stage.

V. USING HLJ IN PRACTICE WITH HELAS: THE HEROINE'S LEARNING SYSTEM

To easily apply HLJ in practice, we developed the Heroine's Learning System (HeLaS) (the acronym HeLaS sounds similar to “elas,” the plural of “she” in Portuguese). HeLaS is a web application that allows teachers, tutors, or educational staff (playing the role of Journey designer), to set up the materials of a preexisting (online) course aligned with the HLJ model. In specific, HeLaS provides a way to create an enhanced version of a preexisting online course that follows the stages of the HLJ model, by merging the information displayed by the LSS with display elements provided by HeLaS. A diagram of HeLaS, including all of its modules, can be seen in Figure 5.

HeLaS encompasses two main structures: (i) the back-end which allows access to the business logic models using a REST API; and (ii) the front-end, consisting of HTML pages that interact with the back-end via a REST API.

The front-end includes several views that guide the user interaction through different steps, depicted as arrows in Figure 5. These views consist of pages built using the Ionic Framework [114] and PrimeNG [115]. Firstly, the users land on the applications' homepage [116]; next they are directed to a login screen where they can register or enter the application using their credentials. They can then use management pages to supervise and change some elements to be displayed by the LSS, throughout the course. These elements are aimed to be integrated in the screens already provided by the LSS.

The back-end, implemented using the Supabase service [117], includes and exposes the data related to the business logic. An entity-relation scheme of the application data models is also included in Figure 5, in the Back-End module. The Profile entity, that contains user data, is related to one Course entity, that characterizes the purpose of the course. The Course entity deploys one or multiple Interaction entities, which represent the different page elements that can be integrated in the LSS. Both the Course and Interaction entities relate to a Journeys entity, that exposes information about the different stages of HLJ, through a Framework associative entity, that is also responsible for providing information about the Supabase inner models.

The set-up of an HLJ-integrated course using HeLaS, can be performed by a Teacher or a Journey Designer, as laid out by the following procedure:

- 1) Check that the given (online) course verifies the necessary prerequisites to be associated with the journey;
- 2) Insert the entire structure of the (online) course into the web application, i.e. register all the videos and texts, quizzes, assessment activities, or other structured information present in the course, preferable grouped by topics;
- 3) Use the HLJ web application to generate a report that associates the entire course structure with the twelve stages of the Heroine's Learning Journey. In this report, each stage of the journey, along with its Narrative, Mission, Challenge, and Assistance, will correspond to the course topics and activities inserted in the previous step;
- 4) Perform tests to validate all configurations, and open the (online) course to the public.

Note that a content sheet for interpretation, better learner orientation, and motivation for each of the twelve HLJ stages was created to support this process. In general, on each content sheet, one can find the descriptions of the Narrative, Mission, Challenge, and Assistance associated to the given stage, as well as the link of the video created to support that stage [118].

A. THE CASE STUDY

To test the potential of the HLJ in improving female motivation for STEM, we used HeLaS for integrating the HLJ into the online course: “Machine Learning, Maths and Ethics: Hands-on,” launched for the first time on the MOOC Técnico platform (the customized Open edX platform of Instituto Superior Técnico) at the end of 2021 [119].

The goal of this online course is to be an introductory hands-on MOOC on machine learning and programming. Additionally, one can find content on the mathematical bases of several algorithms explained from the scratch and ethical discussions on several machine learning models. The self-assessment activities, starting from practicing programming in Python [120] within Google Colab [121] notebooks,

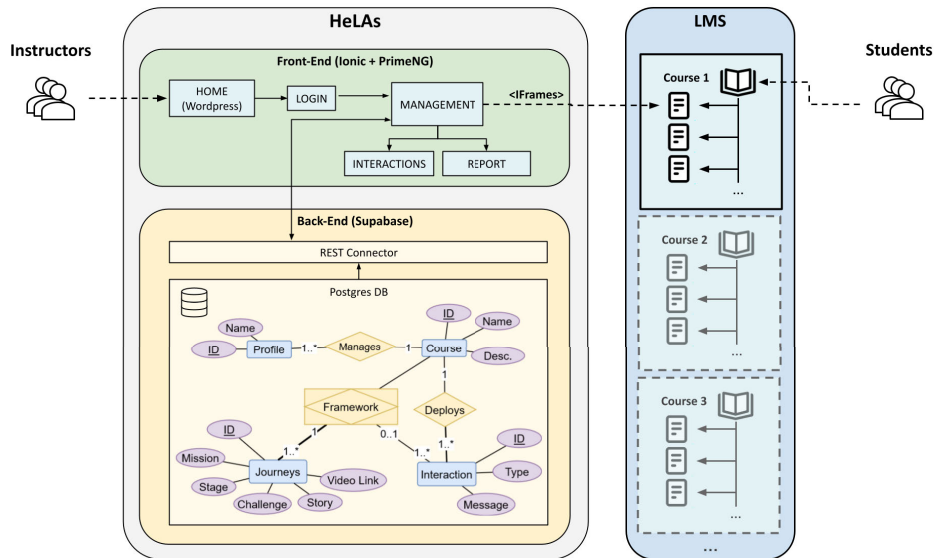


FIGURE 5. Diagram of the HeLaS architecture.

followed by working with realistic data-sets, have the purpose to demystify the complexity of the algorithms involved. The content design and production of this online course follow the guidelines of the Fostering Women to STEM MOOCs (FOSTWOM) Erasmus+ project [122] for creating MOOCs in STEM subjects under a gender balance and inclusive perspective [6], [7]. In doing so, the MOOC has no special prerequisites. It assumes only that participants have attended secondary school. To participate in this online course there is no need to have any previous programming experience. Moreover, all the contents of the MOOC are free of charge, completely online and will remain available to all enrolled users after the end of the current edition, so that they can revisit its content. The online course is composed of six topics:

- 1) **Welcome and introduction**, which introduces what machine learning is;
- 2) **Learning from experience: Machine learning and supervised learning**, which presents the different types of machine learning, and supervised learning in more detail;
- 3) **How we are going to work in supervised learning models**, which describes the standard process of building predictive models, and demonstrates how to program it in Python [120] within Google Colab [121];
- 4) **Data preparation, data exploration and statistics**, that describes and exemplifies the first two steps of the standard process: data preparation and data exploration; and introduces some fundamental statistical concepts needed to better understand machine learning. There are two videos dedicated to each step of the standard process: one video with a general explanation of the main actions due in the corresponding step; and one with a detailed explanation for a particular example

(Solved exercise) that illustrates the given step of the standard process;

- 5) **Training models, evaluating models and matrices**, that describes and exemplifies the next two steps of the standard process: training models and evaluating models; and that gives some introductory mathematical explanations of how some of the algorithms work. Also here one can find two dedicated videos per each step of the standard process;
- 6) **Ethical challenges of machine learning algorithms**, that brings awareness of the challenges of building fair machine learning algorithms.

At the end of Topics 1 and 2 of the MOOC there are graded Quizzes with multiple choice problems, checkboxes, numerical input, etc. Then, in Topics 3 and 4, there are two graded Quizzes that contribute equally to the final grade. Participants with a final score equal or greater than 60% receive a honor certificate of course accomplishment.

In the second edition (2022) of the online course “Machine Learning, Maths and Ethics: Hands-on,” which occurred six months later, an effort was made to translate every text, video transcript, and assessment activities (which included Solved exercises, Tutorials and Cookbooks), into Portuguese. This was done to facilitate access for young Brazilians. As such, the MOOC could be followed in two languages: English and Portuguese. This was the MOOC edition that integrated the Heroine’s Learning Journey through HeLaS.

The dissemination of the first edition of the online course (2021), which due to FOSTWOM project specifications had all contents only in English, relied on University’s social media channels. However, in the second course edition, the one with HLJ (2022), the promotion was carried out through both the University’s social media channels and the *Heroic*

Journeys' project social media [116]. The dissemination messages for the second edition of the MOOC with HLJ included information from the first stage of HLJ, called "Learning Heroine's World." Specific changes made to the original structure of the online course involved the integration of HLJ content sheets with the description, learner orientation and motivation corresponding to each one of the twelve stages of HLJ (see Tables 1 to 3). In general, a content sheet includes the Narrative, Mission, Challenge, and Assistance components, and a link to the short motivational video produced for that given stage, as described in section IV. Throughout the second edition, external resources were provided for supporting the journey, mainly for the Portuguese-speaking Brazilian community. These extra course support activities included a *Discord* [123] group for discussions, a *YouTube* [118] channel for optional supplementary classes, synchronous remote sessions by two dedicated tutors of the course, and optional exercises. In particular, we wanted to captivate young girls from Brazilian high-schools and colleges, since the first contact (homepage explaining the journey in advance), materializing the ideas expressed since the first stage of HLJ.

Taking our model into account, as well as the objectives and topics of the online course described above, we structured the course in the following manner:

- **Act I:**

- **Stage 1 – Learning Heroine's world:** The MOOC tutors send an invitation message through social media to invite (young) people to enroll in the course;
- **Stage 2 – Malala's Call:** The MOOC staff sends a welcome message with a description of the main course challenges, technologies/software involved, proposed assessment activities;
- **Stage 3 – External and Internal Aid:** The MOOC students are asked to complete a psychological personality test [124];
- **Stage 4 – Facing a Storm:** The students watch the videos and complete the activities of Topics 1 and 2;
- **Stage 5 – Transforming fear into strength:** The students are provided with video interviews of influential women in STEM and computer science.

- **Act II:**

- **Stage 6 – The Light of Knowledge:** The students watch the videos and complete the activities of Topic 3;
- **Stage 7 – The Meeting with Athena:** Completion of additional activities;
- **Stage 8 – STEM Ordeal:** The students watch the videos and complete the activities of Topic 4;
- **Stage 9 – The STEM Badge:** The students watch the videos and complete the activities of Topic 5;
- **Stage 10 – Self-Regulated Learning:** The students are asked to submit a final report with their feedback on the MOOC together with their HLJ experience.

- **Act III:**

- **Stage 11 – Reboot The System:** A *Discord* server is provided to allow further interactions, even after course completion;
- **Stage 12 – Becoming a STEM Heroine:** The participants who have earned the certificate are invited to become mentors in the next edition of the course.

During the execution of the course, the *Discord* channel counted with the participation of 61 students and 2 tutors. Through this optional resource provided by HLJ, it was possible to exchange messages, ask questions to course experts and tutors, as well as to access additional materials by the students. On some occasions, it was possible to count with the participation of invited experts in *YouTube* channel special sessions; on other sessions, participants from the MOOC presented their own data analysis.

A questionnaire written in Portuguese was prepared to collect voluntary and anonymous feedback from students' experience while completing the second edition of the online course with the HLJ. This questionnaire was made available online within the MOOC at stage 10 of the Journey, addressing Self-Regulated Learning (SRL). The questionnaire was composed of the following fields:

- 1) Socio-demographic questions about gender, age, country, level of education;
- 2) One multiple response question concerning the motive behind the enrolment, allowing the following options: Personal Interest; Professional Interest; Preparation for University enrolment; Someone's suggestion; Self-improvement; and Curiosity;
- 3) One multiple response question asking how participants learnt about the course, allowing the following options: Social Networks; Friends; Work Colleagues; Professors; Family; News; Through Search; or through institutional dissemination of the MOOC;
- 4) Several 5-point Likert scale questions, measuring:
 - a) How the students agree with the statement "I am aware of gender inequalities in STEM fields", ranged between "Not at all (1)" to "A lot (5)";
 - b) How the students assess the relevance of the HLJ as a motivation to complete the course, ranged between "A little (1)" to "A lot (5)";
 - c) How the students assess the relevance of the framework of the HLJ, with its challenges and the twelve stages, ranged between "A little (1)" to "A lot (5)";
 - d) How the students assess the relevance of including examples of female role models in the STEM field, ranged between "A little (1)" to "A lot (5)";
 - e) How the students assess the relevance of the (dedicated) support provided by experts, allies, and mentors, ranged between "It is not important (1)" to "It is important (5)";
 - f) How the students assess the relevance of additional activities offered by HLJ along their study,

ranged between “It is not important (1)” to “It is important (5)”.

- 5) Question asking if the students would recommend the course to other people (with a yes or no answer option);
- 6) An open response box for feedback and additional comments.

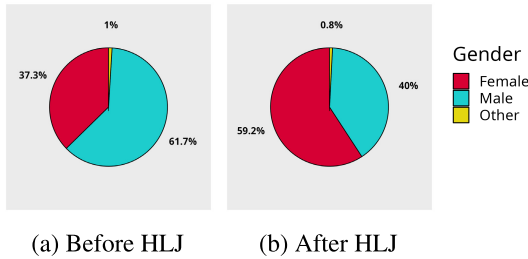


FIGURE 6. Gender distribution before (a) and after (b) the application of HLJ.

1) IMPACT OF HLJ IN FEMALE ENROLMENTS

The first edition of the MOOC (2021) had 311 complete enrollments (317 enrollments were registered in the platform, but 6 cases were excluded from the dataset for having missing fields). Given that the FOSTWOM online course was already designed to captivate a young female audience, it is gratifying to verify an unusually high amount of female participation ($\approx 37.3\%$), when compared with the usual less than 20% female enrollments in STEM MOOCs [57]. Notice that from all of the enrolled female subjects, approximately 23.3% are in our target age range, from 15 to 21 years old (see Figure 6 for the gender distribution, and Figure 7 for the age distribution of female participants in both courses). From the participants who filled in their nationalities ($\approx 36.7\%$ of all participants), approximately 89.5% were Portuguese, 7% were Brazilian, and 3.5% of the participants were from other nationalities.

In the second edition with the HLJ, 368 people enrolled in the course, from which we verified a predominance of female enrollments ($\approx 59.2\%$). This is the highest female enrollment rate recorded for a course in MOOC Técnico platform. From all females enrolled in the course, a considerable percentage ($\approx 46.3\%$) are in our target age range (15 to 21), and a majority of them ($\approx 57.8\%$) aged between 15 and 22. From the participants who filled in their nationalities ($\approx 28\%$ of all participants), approximately 81.6% were Portuguese, 13.6% were Brazilian, and 4.9% of the participants were from other nationalities.

The aforementioned results, gathered with all the students’ enrollment information, suggest that the dissemination stage in the MOOC’s version with the HLJ effectively attracted more female participants, notably in the target age range. In the first edition of the MOOC (2021), 78 honour certificates were obtained, and in the second edition with the HLJ (2022), 67 honour certificates were obtained, which represent circa 25.1% and 18.2% of the complete enrollments, respectively. These completion rates surpass the

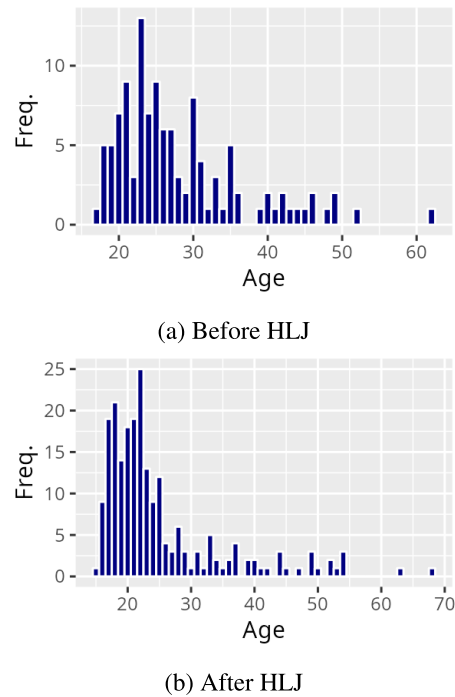


FIGURE 7. Female students’ age distribution in the MOOC’s first edition (a) and second edition with the HLJ embedding (b).

ones identified by Fu and colleagues for STEM MOOC courses, which are on average below 10% [125].

2) STUDENTS’ FEEDBACK ON THE STEM MOOC WITH HLJ

Even though the second version of the online course with the HLJ integrated was attended by 367 participants, we were able to gather only 65 responses to our optional final questionnaire (45 females; 19 males; 1 student preferred not to say). This can be explained by the fact that probably only participants who completed all the course activities reached the survey and were motivated enough to give their feedback. According to those participants, the main reasons that led them to enroll in the course (question 2) were “Professional Interest” (65.7%), “Personal Interest” (62.9%), and “Curiosity” (45.7%), which corroborates the attractiveness of our HLJ-enhanced STEM course, in particular to female students in quest of a STEM career, and suggests that our motivation-enhancing strategies worked as expected for them.

Regarding how participants learned about the course (question 3), the majority of respondents selected social networks (53.8%). Teachers accounted for 24.6%, news accounted for 12.3%, friends and family each accounted for 10.8%, and all the other invitational means encompassed only 1.5%.

Responses to question 4.a suggest that respondents were/became aware of STEM gender inequalities ($M \approx 4.48$; $SD \approx 0.69$), and in particular that the majority strongly agreed that there is a perceived non-balance in these fields (56.9% of the respondents indicated 5 in this scale).

Responses to question 4.b suggest that HLJ was perceived as an important overall strategy to motivate students ($M \approx 3.88$; $SD \approx 1.11$). Besides, in response to question 4.c, the participants also positively assessed the set-up of the HLJ, with its challenges and twelve stages ($M \approx 4.27$; $SD \approx 1.09$). Responses to question 4.d reflected a strong perceived relevance of examples of female role models who contributed to the development of STEM fields ($M \approx 4.72$; $SD \approx 0.55$). The majority of respondents (75.4%) considered that it is extremely important (gave an importance rating of 5) to have these female examples [41], [94].

The responses to question 4.e also allowed to verify the perceived relevance of the HLJ supporting roles, encompassing experts, allies and mentors ($M \approx 4.41$; $SD \approx 0.96$), in encouraging and guiding students through their learning journey. Furthermore, the responses to the question 4.f ($M \approx 4.23$; $SD \approx 1.02$) led us to conclude that having additional activities/support groups that are leveraged by resources, such as a *Discord* server or *YouTube* channel, makes a difference in the learning process.

Among all 65 respondents, only one would not recommend the course to other people (question 5), further suggesting that the design and content of the course, together with the HLJ motivational strategies worked well for them. Moreover, 15 respondents expressed a positive feedback in the open comments field. In the box below, we point out 8 comments that reveal some interesting aspects highlighted by participants about the second edition of the course.

Open comments on the 2nd edition of the MOOC (Translated From Portuguese)

“Thank you for offering this course with amazing and free material.”
(Female, 20 years old, Brazilian)

“The entire course is very interesting and differentiated, super complete because it includes many things from different areas and with a great opportunity to encourage women who are always in the minority, so it motivates, notably us young woman, with incredible opportunities such as this, it was a super amazing experience from the classes to the videos and everything, everything was amazing.”
(Female, 16 years old, Brazilian)

“I found [the course] very interesting, and if I have more opportunities I will definitely recommend it to other people. I loved everything from the videos to the classes with [the tutor] Lari. Thank you for giving us the opportunity to learn more about it and also for encouraging girls like us in computer science.”
(Female, 17 years old, Brazilian)

“The experience that the course provided was very interesting, because in addition to relating to my interest, information technology, it encouraged us that no matter who we are, we should follow our dreams, regardless of gender.”
(Female, 15 years old, Brazilian)

“I found the video lessons extremely well done, with clear examples and sticking to the essentials, leaving the detail for individual analysis in the support materials. I would have liked to have had classes with this level of quality in the vast majority of courses at [the student's institution]. My congratulations and huge thanks for what they taught me and for the material they provided me so that I can continue my learning outside of this course. Although I am not female, I know that this course is not intended to exclude me because of my gender (although it was designed for women) but to awaken me to the theme of gender equality and encourage my contribution to it, as far as my reach. Thanks again.”
(Male, 27 years old, Portugal)

“The course was very cool and I highly recommend it.”
(Female, 16 years old, Brazilian)

“I loved the course, it was very important for me and I learned a lot through the journey.”
(Female, 20 years old, Brazilian)

“Very good, it was an amazing experience.”
(Female, 15 years old, Brazilian)

VI. DISCUSSION

A major goal of the HLJ when applied to a STEM course is to support young women in having a positive learning experience. That is, to ensure that female students are improving their technical skills on a given subject, but at the same time guarantee that they are also able to boost their self-esteem and confidence to work in STEM, being motivated to pursue STEM studies and/or a STEM career [8], [9].

With such a goal in mind, we have applied the HLJ model to a preexisting online course that constitutes a STEM MOOC with a gender balance and inclusive perspectives by design. We achieved an increase in total number of enrolled female students in the second edition (2022) of such an online course. Not only the number of young girls enrolled in the HLJ-enhanced course has increased relatively to the first edition (2021) (see Figure 7), but it also constitutes the highest female enrollment rate recorded for a course in MOOC Técnico platform [126]. This suggests that the dissemination strategies we focused on: the University's

social media channels, as well as the *Heroic Journeys*' project social media (all carried out in Portugal and Brazil); were successful, in particular the messages sent via the first stage of HLJ: "Learning Heroine's World." At this initial stage, course applicants are introduced to their journey and the opportunity to face unknown challenges. The importance of this first stage is significant, as it serves as the starting point for the entire narrative, working to arouse curiosity and interest, creating an emotional connection between the story and the audience. Additionally, it aids in establishing clear goals or the mission. The first stage of the HLJ is not only an introduction to the story but also a fundamental element that prompts action, generates interest, and lays the groundwork for participating in the course. This stage extends an invitation to the audience to embark on an educational journey in the STEM fields.

In the narrative structure of the HLJ, some stages have a strong motivational component, materialized through information made available in content sheets and videos. For instance, "External and Internal Aid" revolves around the core concept of motivation, encouraging students to make an effort to better understand themselves and questioning: "Which topics cause you the most concern? What makes you think/feel differently?". At the same time, in the third stage of the HLJ: "External and Internal Aid," students received external support from content experts, mentors, and tutors, that helped them to overcome technical difficulties. In our opinion, several approaches can assist in student motivation, ultimately facilitating female participation in STEM fields. One of these approaches is Project-Based Learning (PjBL), where students pursue solutions to non-trivial problems, by asking and refining questions, debating ideas. All these activities were present in the FOSTWOM MOOC, together with analyzing datasets, making predictions, and drawing conclusions [127].

The respondents of the MOOC final questionnaire indicated that the additional resources provided by the HLJ, together with the support provided through experts, allies and mentors played an important role in their learning process and promoted a stimulating environment along their course experience. They found particularly important the inclusion of female role models, as well as the additional *Discord* and *YouTube* resources. Remarkably, their answers corroborate the relevance of including role models as a source of motivation for (female) students [92], [93], and connect to the HLJ-included profiles of twelve STEM female role models (and videos with women in STEM careers and education interviews) by the fifth stage: "Transforming Fear Into Strength."

"STEM Ordeal" is the eighth HLJ stage, and it serves as a reminder of the technical difficulties to overcome in a STEM course. This includes, for instance, mastering programming sufficiently to be able to work with databases and/or understanding mathematical formulas and procedures that follow the construction of machine learning algorithms (Topic 4 of the MOOC). These activities require focus,

concentration and a lot of tenacity to overcome mistakes that happen frequently when working with code. After that, in Topic 5 of the MOOC, the steps of training models and evaluating models also require similar skills.

Finally, several comments submitted in the questionnaire indicate that the dynamics of the HLJ model have shaped the learners' attitudes towards STEM learning. We can conclude after this case study, that HLJ has the potential to provide an interesting and different learning experience, addressing issues of gender balance in STEM in ways that are motivating for women and empathizing with many people.

VII. LIMITATIONS AND FUTURE WORK

Before launching the next initiative of a course integrating the HLJ, we intend to address and implement the improvements of some of the stages of HLJ that have been identified by experts (see end of section IV-B: "The Narrative of the Heroine's Learning Journey").

This case study also made us reflect on the possible impact of the HLJ on people who don't identify themselves with the female gender. We have tried to address the specific needs of young women in STEM, but we hope that all those who experience biases or lack of support in accessing and attending STEM courses can also benefit from this model, or its further developments.

Concerning the infrastructure (HeLaS), it is important to mention that a comprehensive evaluation of its technological functioning has not been conducted. Although the application of HLJ to the given online course did not encounter technical issues, no evaluations or research have been carried out regarding its usage by other users and institutions. These additional evaluations and research can provide information to improve the infrastructure and ensure a more effective implementation of HLJ in different (online) contexts.

We also plan to develop training materials for teachers and educators interested in using the HLJ model. Additionally, we will create new materials based on the gained experience, including new versions of stage videos. These enhancements and plans will enable new experiments and evaluations of the ability of HLJ to motivate young women, while also exploring the potential impact of HLJ on the overall participation of people identifying themselves with other genders. Furthermore, we encourage the use of our infrastructure, HeLaS, by other universities and educational institutions interested in implementing similar approaches.

VIII. CONCLUSION

Even though STEM education leverages the technological development of society, it still faces a deficit of female participation, which we believe to difficult the proliferation of a culture of inclusion, where diverse points of view are taken into account. As such, in this paper we propose Heroine's Learning Journey, a narrative-based model that aims to mitigate the lack of female participation in STEM. The model is based on the established heroic journey narratives of Joseph Campbell and Maureen Murdock. It aims to achieve its goal

TABLE 1. Heroine’s narrative walkthrough - Act I.

#	Stage	Narrative	Act I - Empowerment		Assistance
			Mission	Challenge	
1	Learning Heroine’s world	The Learner’s initial world is full of anguish, doubt and lack of confidence. She is involved in several daily activities that include studies, family and leisure. She needs to improve her STEM skills, and she wants to be part of a cool group. She wonders herself about the possibility of a STEM career, and believes that the odds are on her side.	To enroll in the course and understand the rules of the journey.	Engaging in the journey.	Tutors, Teachers, the Mother Goddess, and Allies disseminate the journey included in the STEM course through social networks, and send an invitation email message to newcomers.
2	Malala’s Call	Having accepted the agreement and the proposal, the Learner receives a motivational and symbolic message from the Tutor, Teacher or Allies. This message can arrive digitally, through audio, video, text or other media, and briefly present the challenges that are supposed to be overcome during the course/ journey, the applications of the content to real life situations and a brief presentation of the technologies and tools that will be used during the course.	To read the welcome message with instructions, and participate in others’ activities if the course proposes any.	Understanding the journey structure.	Tutors, Teachers, and Allies send a welcome message with the general advice to be followed during the learning process, a detailed explanation about the course content, the evaluation activities and final project/ exam, and about the support team involved. Allies: An expert on the given STEM subject can participate giving an interview or testimonial, maybe at the first day of the course, or in a previously recorded video interview, virtual meeting or welcome message.
3	External and Internal Aid	It is time for some external aid to arrive in help of the Learner from the side of content experts (Tutor; Teacher; Allies), as well as motivational support needed for enduring the journey. For instance, if it is expected that female students are afraid of being mistreated by others when performing, and have a past experience of cultural barriers and/or rejections based on gender, this is the time for challenging these misconceptions. In order to successfully overcome this stage, several female role models in STEM will be presented to the Learner.	To perform the test.	Acquiring self-knowledge.	Tutors, Teachers, and Allies prepare a personality test with questions that help to profile the students, e.g. questions that help to identify Learner’s preferences, fears, and expectations, as well as strengths and weaknesses.
4	Facing Storm	Learning content, new platform(s) and technological environments are now part of Learner’s life. This is definitely the time of greater effort, so she shall face and overcome the storm with all the commitment and focus of a true heroine. The Learner must engage in more theoretical content, in order to overcome their initial sensed difficulties.	To allocate time for studying the presented content, for searching other related content, and perform course activities.	Managing free time, tension, procrastination, and overcoming technical difficulties.	The Teachers or Tutors expose the Learner to the videos, podcasts, tutorials, manuals, and other basic course content. Athena intervenes as soon as the Learner has seen all the videos, and revised and practiced the theoretical content: the Learner will receive a message from Athena, stating that she has just won an extra chance, in case she needs to increase her grade in stage 7 “The meeting with Athena.” This activity is added as a bonus and is designed to function as a reward for the effort and focus in the search of knowledge.
5	Transforming Fear Into Strength	By now, the Learner has probably increased her self-confidence while engaging with STEM content. She knows the basics, she gained her voice by posting comments on forums, and by engaging in specific collaboration tasks. When someone tells her that she has no special skill for coding, performing calculations, analyzing data, or designing tools and applications, the Learner replies “Yes, I can!”	To explore videos and texts with tips and suggestions, to watch videos / interviews with experts in STEM fields, and to visit companies in person or online.	Gaining self-confidence and overcoming difficulties.	Tutors, Teachers, and Allies provide course content and external support, such as tips and suggestions, provide videos of interviews with researchers from academic centers or companies. These interviews can be in-person or online.

TABLE 2. Heroine's narrative walkthrough - Act II.

		Act II - Growth			
#	Stage	Story	Mission	Challenge	Assistance
6	The Light of Knowledge	Considered as one of the most important stages, as it unfolds, the Learner needs to understand her role in this new world. Yes, the Learner has entered into a new world! At this time, the Learner is used to code, to manipulate mathematical formulas and concepts, and to establish relations between them. All of the acquired knowledge allows her to develop new projects and get involved in STEM activities.	To solve problems, to manipulate data, to deal with statistics, and to create programs and projects.	To become a more mature Learner, accepting this new condition.	Tutors, Teachers, and Allies challenge the Learner to practice the course content, including problem-solving activities, data manipulation, mathematical computations, statistical analysis, and with quizzes. They deliver course evaluation activities, previously announced.
7	The Meeting with Athena	This stage will require that the Learner puts into practice everything she has learned so far. The Learner went through the STEM course basics and feels strong enough to proceed with her studies. The Learner also deals with algorithms and mathematical formulas for conducting data analysis or other important applications in the fields of STEM.	To prepare presentations, group tasks, individual projects, quizzes, questionnaires, and to analyze solved exercises.	Recognizing inspirations, and identifying herself with role models.	Tutors, Teachers, Allies provide individual or group challenges, propose project presentation topics for the learner to experience real-world applications. If the Learner has already seen all videos and went through theoretical content of stage 4, Athena offers the Learner a bonus and/or a reward.
8	The STEM Ordeal	What can the Learner get from the journey now? She acquires more self-confidence, and self-regulation. At the same time, she becomes proficient and is able to propose technological artifacts by herself, discover new connections between mathematical formulas and visualisations. The time for the big challenge is coming, and the Learner needs to get ready, get organised and prepared for the next stage...	To perform self-assessment exercises, to explore content, and to train.	Acquiring self-analysis, skill growth, and practice.	The Tutors, Teachers, and Allies provide support for Learners to carry out self-assessment activities, encourage learners to collaborate on forums and social networks related with the course content.
9	The STEM Badge	The Learner is now about to face her big journey's challenge or final assessment, and she is well prepared to face the final clash of deliveries in this course. She feels confident to present the project, to carry out a final exam. The Learner possesses all that is needed to successfully overcome the final evaluation proposed by the Teacher/Tutor.	To perform the final assessment, e.g. a final quiz, task, or practical challenge.	Obtaining the results of the last assessment.	The Tutors and Teacher launch the final assessment.
10	Self-Regulated Learning	The Learner, who has faced great challenges and encountered few enemies, now receives the well deserved prize for all her efforts. It is time to have access to the final grade and report evaluations of the course. Also, with all of her practice and acquired new skills, the Learner is qualified to successfully proceed her STEM studies.	To submit a final report, and to obtain a final grade of the course, and final instructions.	Applying self-regulation to learning.	The Tutors and Teachers provide a final evaluation, a final grade of the course, and final instructions that consolidate the main tips for succeeding in the course.

TABLE 3. Heroine’s narrative walkthrough - Act III.

		Act III - Return			
#	Stage	Story	Mission	Challenge	Assistance
11	System Reboot	The Learner becomes aware of the full process of becoming a true heroine. This stage offers the Learner the possibility of earning the Learner Heroine’s status.	To complete a final course survey. Depending on the format of the course, the Learner must join a secret community group with peers, or perform an extra-curricular action.	Becoming a new person.	The Tutors, Teachers, and Allies provide final questionnaire for evaluation/ research of the course. They also offer participation in specific discussion groups on the subject of the course.
12	Becoming a STEM Heroine	What is the final challenge? How does the Learner become a Heroine? Where and how will she share her knowledge? What will happen to Learner now? Only true Heroine Learners are able to respond to these questions and complete this stage.	To receive a certificate for her bravery and acquired skills. The Learner will still need to help a colleague, mentoring her during the next edition of the course.	Becoming a Heroine.	The Tutors, and Teachers provide a certificate or final report that proves the bravery and skills acquired by Learners. They also offer the opportunity for Learners to become mentors in the next edition of the course.

TABLE 4. HLJ workshop participants.

Role	Country	Age	Gender	Experience (Years)	Works in STEM?	Experience in STEM (Years)
Teacher	Portugal	46	Male	14	Yes	23
Assistant Professor	Portugal	47	Female	23	Yes	23
Researcher	Italy	38	Male	8	Yes	10
Assistant Professor	Spain	57	Female	33	Yes	33
Assistant Professor	Portugal	47	Female	25	Yes	25
Media Producer	Sweden	57	Male	20	Yes	8
Instructional Designer	France	58	Female	10	Yes	5
Instructional Designer and Project Manager	Italy	30	Female	6	No	N/A
Ph.D.	Sweden	35	(Rather not answer)	10	Yes	10
Assistant Professor	Spain	57	Female	33	Yes	33
Instructional Designer	Italy	32	Female	7	No	N/A
Media Pedagogic and Video Coach	Sweden	57	Female	34	Yes	2.5

through several motivation techniques tailored to the female audience, such as the inclusion of narrative roles that are associated to important or mythical female characters, and the presentation of female role models. HLJ defines a narrative divided into three acts, which themselves are divided into more specific stages. Each stage contains a Narrative, Mission, Challenge and Assistance. The structure and contents of this narrative was evaluated by experts/scholars who deemed them interesting due to adequate pace and felt relatedness. However, the same tests revealed some of HLJ limitations such as the clarity of some of the explanations. This feedback was considered for improving the explanations of the model.

After present HLJ, we have also described how a practical system titled Heroine's Learning System (HeLaS) can be used to integrate the HLJ to an online course. In particular, HeLaS was deployed to shape the course: "Machine Learning, Maths and Ethics: Hands-on," previously launched in the MOOC Técnico platform. Along with the activities provided by the MOOC itself, supporting *Discord* and *YouTube* resources were provided, and were mainly targeted at Brazilian participants. Several insights were extracted from the student database of the course before and after the application of HeLaS. Although the first edition of the course already presented *per se* an abnormally high female participation for a STEM course ($\approx 37.3\%$), with HeLaS, we verified a predominance of female participation ($\approx 59.2\%$), of which 46.3% were in our target age range of 15 to 21 years old. Even though this clearly presents a much better balance than before, the opposite gender participation may have to be counteracted, an issue that can be explored in the future. Based on the feedback that we collected from students' experience, we then explored possible reasons behind this improvement. By asking participants several questions, we could conclude that being enrolled in this MOOC allowed them to acknowledge the usual STEM gender imbalance. Also, when finalizing the online course, they revealed to support the initiative, and to embrace its structure and motivating nature. In particular, they found relevant the inclusion of female role models, additional tutors roles, and they appreciated the existence of learning support resources. Finally, several optional free-written student feedback rendered the students' participation in the online course embedded with the HLJ useful and attitude-shaping.

AVAILABILITY OF DATA AND MATERIALS

The dataset and outputs supporting the conclusions of this article are available in the *Heroine's Learning Journey: Motivating Women in STEM Courses Through the Power of Narrative* repository: <https://osf.io/mceg6/>.

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