



STEAM CITY KITS

A project for primary schools that combines storytelling, hands-on activities, and physical

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KEYWORDS

*STEAM activities
Primary Schools
Storytelling
Aveiro Tech City
Physical Computing*

ABSTRACT

This paper presents a comprehensive description of the STEAM City Kit project, an exploratory project developed according to a Framework for Innovation process model, as part of the Aveiro Tech City project, and designed for primary school students and teachers. The kit, which consists of 2 children's stories with hands-on activities, an Arduino, and a wide range of sensors, was developed by a transdisciplinary team from the University of Aveiro and distributed to over 30 schools in the municipality of Aveiro, Portugal.

PALABRAS CLAVE

*Actividades STEAM
Escuelas primarias
Cuentacuentos
Aveiro Tech City
Computación física*

RESUMEN

Este artículo presenta una descripción exhaustiva del proyecto STEAM City Kit, un proyecto exploratorio desarrollado según un modelo de proceso del Marco de Innovación, como parte del proyecto Aveiro Tech City, y diseñado para estudiantes y profesores de primaria. El kit, que consta de 2 cuentos infantiles con actividades prácticas, un Arduino y una amplia gama de sensores, fue desarrollado por un equipo transdisciplinar de la Universidad de Aveiro y distribuido a más de 30 escuelas del municipio de Aveiro, Portugal.

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1. Introduction

Humans have always lived with some sort of technology. But its evolution, especially in recent times, is so breath-taking that technology has never been so present in our lives as it is now. Even in educational contexts which, in general, are prone to resistance to change, in little more than 30 years, progress has been so rapid that it has taken us from the pencil to the smartphone and from the chalkboard to the smartboard. It is therefore of the utmost importance to enable children to develop knowledge about the natural world, but also about man-made objects (Bers, 2008), such as technological artefacts, and while doing so, make the most of them. Training citizens in Science, Technology, Engineering, Arts, and Mathematics (STEAM), as opposed to omitting the relevance of the Arts (Stroud & Baines, 2019) and opting for a STEM concept (Robelen, 2011) becomes fundamental so that they are provided with the tools can fully live out their lives and also contribute, in a sustainable manner, to technological development, with a concern with the common good, as emphasised by the United Nations (UN), namely in the 2030 Agenda for Sustainable Development and in the goals “to transform our world” (UN, 2015). Thus, the mastery of technologies is crucial for the development of fundamental literacies for a future in which children are prepared for the constant challenges of scientific and technological evolution. The development of digital skills plays therefore an essential role in grasping the skills of the 21st century and should be considered a universal educational goal (Kloos et al., 2018), especially from the early years of schooling. However, despite its relevance and all the progress made over the years, the lack of preparation of teachers (Guerra et al., 2018, 2020) for the widespread use of technologies persists as a strong barrier to the use of ICT in educational settings. Various initiatives, as well as national and international agendas, have tackled these challenges from all sorts of angles (i.e.: Training programs, workshops, seminars, and projects organized and funded by national agencies dedicated to the subject) and even got an additional boost with all that happened and was rushed into practice with the COVID19 pandemic and the lockdowns. However, positive signs such as the number of teachers, students and staff that got their digital competencies certified, cannot overlook the fact that thousands of teachers and students were left in dire straits not quite sure of how to carry on with their teaching and learning activities (Roque et al., 2021). In addition to the poor, yet gradually improved, training of teachers, some authors have also pointed out for some time the lack of educational resources (Kennedy & Odell, 2014). This reality has also seen noticeable improvements and has benefited from the increase of user-generated content published and disseminated online through social media, the spawning of new practices close-knit with social media platforms such as Tik Tok, Instagram, Facebook and Twitter and, unfortunately, the amount of time many had on their hands during the lockdown or other COVID19 related confinement periods. It has been affirmed for some time that is crucial to link the training, ongoing, of teachers with the research and development (R&D) of technological resources for education that aim to promote the inclusion of all children and young people in active learning in the various STEAM areas (Freeman et al., 2014). With this in mind, the STEAM City Kit project emerged as part of the Aveiro Tech City project (Aveiro Tech City, 2022) and was designed for primary school students and teachers.

Aveiro Tech City is an initiative of the Aveiro City Council aimed at using technology as a means to improve the quality of life of all citizens, by helping management entities to collect and share information on new and exciting ways to manage the city, from mobility, education, culture and environment. This initiative includes several projects in different areas from Education and Smart Mobility to Telcom infrastructures and the Internet of Things. In the area of Education, the Aveiro STEAM City project aims to contribute to the digital skills training and qualification of human resources enabling them to make a difference in the ever-evolving digital era (Escalona, Cartagena & Gonzalez, 2018). With this empowering goal in mind and within the scope of the Aveiro STEAM City project, several Tech Labs were created all across the municipality’s primary and secondary public school network system. However, despite the number of actions conducted, there was still a need for developing and providing solutions adequate for the 1st cycle of basic education, encompassing the first to the fourth year of schooling in the Portuguese education system, and which would support a STEAM approach in this particular segment. This opening brought the research opportunity to cross several dimensions of technology, education and multimedia communication. The teaching of knowledge and skills in the area of IT, electronics and logic face several difficulties in young people aged between 5 and 7 years. On the one hand, reading and comprehension skills at these ages are not yet fully acquired or consolidated, a fact that prevents the use of the numerous teaching materials and tools that are available for other age groups. On the other hand, we see a scarcity of teaching resources available in the market and education research specifically for this age group, since the introduction of knowledge in the area of technology involves a certain degree of technical complexity. Pedagogical approaches such as Dynamic Learning and Active Experimentation of Knowledge stand out, which seek through technology to place the student at the centre of the teaching-learning process. These approaches are strongly supported by constructivist and connectivism theories. The first is based on the idea that new knowledge is apprehended in strong articulation and dependence on knowledge already pre-acquired by the subject. In turn, connectivism holds that learning is not a process of a purely internal nature and is rooted in the social dimension of community.

In line with these two approaches, the context of this project allowed us to investigate the role that narrative and storytelling can have in teaching IT to these children, placing the student at the centre of the learning process.

The inclusion of stories combined with content customization strategies creates a strong feeling of empathy and motivation in the child to carry out the activity

The team from the Department of Communication and Art from the University of Aveiro, most of them members of the DigiMedia research unit, was assembled and took on the challenge of designing, developing and delivering a STEAM kit adequate for those students and those very challenging school years. The multidisciplinary team that put together and developed the STEAM City Kit presented in this paper, although confronted with non-foreseeable issues during the project (no one can ever expect a full global pandemic) was able to design a kit with both room and potential to grow with its users and with the surrounding environment. To do so the team opted for the adoption of physical computing concepts as a solution for approaching the STEAM-related challenges pondered and, when doing so, made it clear that these should not be confused with concepts tied to tangible programming. In the case of tangible programming, it may be characterised, in nutshell, as one that uses physical objects to obtain an algorithm which will generate an input (either in a computer or in a robot) which, in return, will generate an output. To a certain extent this can be considered an integral element of physical computing, but not per se. Physical Computing at its core is characterised by the development of a physical product, which naturally requires a specific process and tools. In other words, and according to Capáy and Klimová, “physical computing consists of the design and realization of interactive objects, installations and support student’s creativity to develop tangible and concrete products of the real world.” (Capáy & Klimová, 2019, p. 1). It allows a holistic experience and the involvement of different areas of knowledge. This made all the sense to the UA team for, according to Krathwohl (Krathwohl, 2002), the deepest levels of learning happen when students are constructing, creating, and getting hands-on with learning materials. Furthermore, according to the student’s point of view, physical computing has a greater impact than a more traditional screen-based experience for it is focused on ideas or concepts, rather than restrictions (Sentence et al., 2017). For all of these reasons, pursuing a Physical Computing approach presented itself as the best option when trying to balance a holistic approach and different STEAM areas. Furthermore, despite some existing projects in Portugal, there are still few studies (albeit exploratory ones like this one) directly involving Physical Computing and primary school pupils and teachers.

This paper is organized into the following sections. An Objectives section, where the main objectives of the project are described, as well as the purpose of the paper; a Methodology section, where the methodology followed for the project’s development is described; a Results section, where the main results obtained throughout the project are presented, i.e. the resources and artefacts produced; a Discussion section, where the results are looked at according to a context and consequence point of view; and finally the Conclusions section that provides the paper’s wrap up and provides some hints as to the short term steps that will be taken regarding the project.

2. Objectives

The paper provides an overview of the project’s genesis, the work accomplished despite many of the issues associated with the COVID19 pandemic and, towards the end, some inner team reflections already gaining form and aiding the definition of the STEAM City Kit project’s next steps. The project described in this paper aimed to develop a kit suitable for aiding an in-classroom approach to STEAM-related content at an early age and at a primary school level, capable of dealing with presenting challenges that include electronics paired with other engaging activities. With these pointers in mind, the team decided to design and deliver not only an electronics kit but also provide a set of activities that would potentially appeal to their creativity, sensibility and curiosity in learning the basic principles of computing. The team ended up also including in its line of thought the idea that this initiative should also contribute to raising young children’s awareness and interest in these mind-opening fields, as well as the development of critical thinking regarding the challenges proposed (Bassachs et al., 2020). The whole team also agreed that the kit should gradually make its way into the classroom. In this paper, another objective discussed and further implemented is also described in some detail, which is the design and completion of the training sessions for the primary school teachers that will hopefully use the kit with their students. As further described in the “Methodology”, “Results” and “Discussion” sections of this paper the design, implementation, testing, training, distribution and dissemination stages provide a very interesting insight into how the project was developed.

3. Methodology

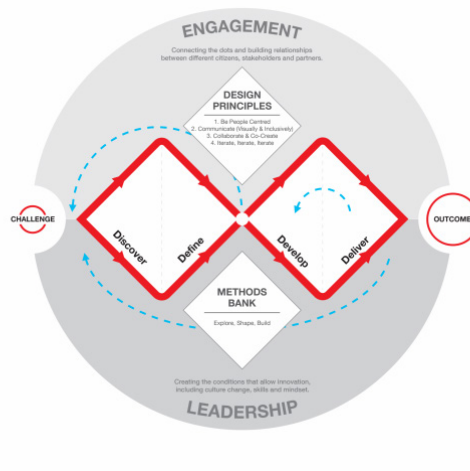
The design, development and delivery of the STEAM City kit were steered according to the framework for innovation model proposed by the Design Council (Design Council, 2019). The adoption and deconstruction of this framework were done by a multidisciplinary team, from the University of Aveiro, involving researchers from the areas specialized in science and technologies in communication and design with previous experience in the development of STEAM-related activities. From a methodological perspective the adoption of the Framework for Innovation, an improvement of the Double Diamond model (Design council, 2019), was assumed as a manageable risk, but one considered worth taking, due to its little use in the field of Education. The team was aware of this fact but considered it adequate for its widely use in co-design processes of new products and its structuring in four

phases and its close connection with the process idealized by the UA team. The Framework for Innovation, much like the Double Diamond Model, includes the following phases and concerns:

1. The discovery phase is in which, after the identification of the challenge/problem, different issues are explored, insights and user needs to be gathered and ideas generated. It is the phase in which divergent thinking guides much of the work done.
2. The definition phase is where problems are defined and refined, providing a framework for further work and tasks. This phase encompasses much of the convergent thinking that enables the team to focus and bring into view what will be effectively done.
3. The development phase in which solutions are created and explored. This stage, although also considered fuelled by divergent thinking keeps activities gravitating around core ideas and concepts previously established in the definition phase.
4. The delivery phase is in which the results (i.e.: service, product, concept, idea, etc) are tested and evaluated, rejecting parts that do not work and improving on those that do. By bringing the team back to convergent thinking the overall project results reach a certain maturity that enables the team to transfer them to another party (i.e.: client, community, network, etc.).

The Framework for Innovation’s iterative nature assures that during each stage there is always the possibility of taking a step back and reviewing and improving the work and results derived from previous stages. These iterative moments are illustrated in figure 1 in the form of dashed line arrows. This model is, therefore, a model that requires constant reflection and evaluation at all stages of the process, as evidenced by the image below.

Figure 1. Framework for Innovation.



Source: Design Council, 2019.

In addition to each of the core concerns of each of the stages already outlined, this framework also steers the ongoing work according to four design principles, as defined by the Design Council (Design Council, 2019). These principals, highly in tune with the UA team’s approach to the challenge at hand, are:

1. Put people first > Start with an understanding of the people using a service, their needs, strengths, frailties, and aspirations.
2. Communicate visually and inclusively > Help people gain a shared understanding of the problem and ideas.
3. Collaborate and co-create > Work together and get inspired by what others are doing.
4. Iterate, iterate, iterate > Do this to spot errors early, avoid risks and build confidence in your ideas.

The following section will describe the results attained through the application of the Framework for Innovation.

4. Results

The results of this project may be divided into multiple dimensions. There is a design and product development dimension, which in practical terms may be understood as the STEAM Kit itself; a concept dimension, that includes the main idea that consists of designing activities that are made up of a story, an arts and craft activity and a physical computing activity that are all tied together according to an aggregating narrative and, finally, a practical dimension that may be understood as the design, assembly, distribution, experimentation and training activities conducted in all the schools involved in the project.

4.1 The Design and product development dimension

The results attained, as for the product dimension of the project, consist of a kit that includes 2 children's stories with both hands-on and physical computing activities that resort to the Grove Arduino® Kit.

Three main beliefs guided the design of the project results first of which was the need to correlate the technology-related educational activity with the context of a story told at the beginning of the activity, thus dividing the temporality of the experience into two distinct moments. This decision was based on the provisional hypothesis that the knowledge and technical competence conveyed by the activity are more easily acquired if the student feels involved, through the mechanisms of empathy, by a story. Taking into mind the need to reinforce the involvement and motivation component, the project also included moments of personalization by the student. These moments would also be used to fuel the student's creativity and establish a bridge between the areas of visual arts and graphic expression. Last but not least, the activity was designed so it could be replicated at home, or out of the more formal school environment, autonomously and without the need for a computer, tablet or smartphone.

In the children's stories, emotional factors were taken into consideration to promote, among other things, the possibility of addressing social and emotional issues through the story and generate empathy between the children and the resources developed, a view already discussed in related work (Erol, Erol & Basaran, 2002). The first story is called "O dinossauro Tozé-Rex" (Tozé-Rex the dinosaur, illustrated in figure 2, and it portrays a dinosaur called Tozé-Rex that has a hard time making friends and fitting in. The story provides de readers with a context, some characters, a storyline twist, and an ending with some closure.

Figure 2. Cover and some imagens from the book "O dinossauro Tozé-Rex".



Source: Raposo & Vairinhos, 2021

The child is invited to build, through a hands-on activity, an interactive postcard involving sensors, actuators and the Arduino about a particular episode in the story. To make the process of electronic connections between the sensor, the actuators and the Arduino easier, the activity was conceived in such a way that it was carried out using the visual schemes of the book itself as illustrated in figure 3. On the other hand, the activity was pre-programmed by the research team, allowing the child to focus on the concepts of flow between sensors, actuators and the board.

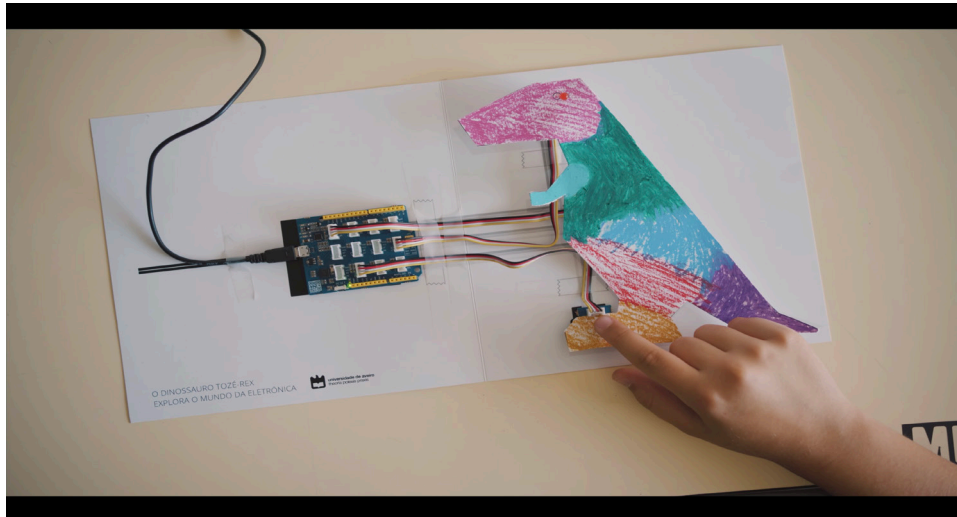
Figure 3. Part of the step-by-step script in the Tozé-Rex activity book.



Source: Raposo & Vairinhos, 2021

The activity consisted of developing a cardboard scenario, in which the character Tozé-Rex is represented. The child installed a light sensor on the dinosaur's paw, an LED in its eye and a speaker on its body. According to the story, the dinosaur lost its menacing look and became a friendly being when it felt the tickle that a mouse gave it on its feet. In figure 4 we can see a child experiencing the result of the activity. The dinosaur was customized according to the student's creativity and imagination, as well as the interpretation of the story. When the child touches the dinosaur's foot, his eye blinks and a loud laugh is heard. Motivated by trying to bring the main character of the story to life, the child recreates the narrative episode, indirectly, apprehending the fundamental concepts of input, output and processing of physical computing

Figure 4. An example of the final result of the activity.



Source: Raposo & Vairinhos, 2021.

The second story, entitled “Madi, Uma menina espacial” (Madi, a spacial girl), illustrated in figure 5, portrays the adventures of a little girl who is the first Portuguese astronaut from the city of Aveiro. This story was created and tailored with the goal of stimulating a greater empathy from female students and helping motivate and generate a greater interest in the field of electronics and informatics. Space-related themes had already been proven as interesting in other STEAM projects (Piila, Salmi & Thuneberg, 2021) identified in the literature review conducted when discussing themes and stories for the second book.

Figure 5. Cover and example of the book “Madi, a spacial girl”.



Source: Raposo & Vairinhos, 2021.

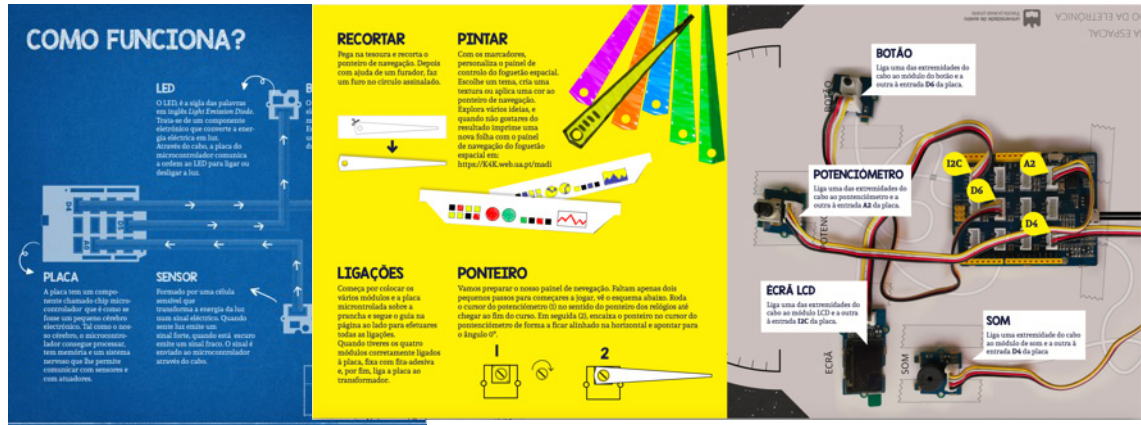
An electronic resource (Arduino board with different sensors) was developed and associated with each story so that students could be invited to create and build something correlated with the story they had just read. The Madi story challenges the student to create a spaceship and help send supplies to the Alavarium Space Station. Besides all the electronic setting-up that the student has to do; they also have to cut out figurines and paint/ decorate them. The strategy employed in this case, in addition to the story that is previously told, consists of a game intended for 3rd-year students, whose math curriculum program involves learning angles and their amplitude.

The game was pre-programmed in the Arduino provided with the kit and challenges the students to guess the angle of the trajectory of a spaceship. The theme was previously introduced in the story and the child, during the activity, customizes the spacecraft and its environment. It should be noted that all these activities come with

a step-by-step guide so that students are able to carry out the suggested activities almost autonomously. As the teachers are considered agents of change and support in the learning process and in order to facilitate the kit's inclusion in formal educational settings, the project provided teacher training sessions. These will be further described in another section of this paper.

In addition to the step-by-step guide, each activity book includes a section where teachers and students can read about how each electromechanical component works. Figure 6 illustrates some of these explanations.

Figure 6. Examples of the explanatory section of one of the activity books.



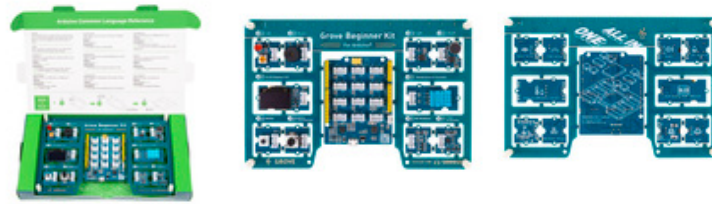
Source: Raposo & Vairinhos, 2021.

One of the tasks performed during the Discovery phase involved the development of a market and state-of-the-art analysis as well as some additional literature review (Juca-Aulestia et al., 2021; Chapman, Barton & Garvis, 2021), to identify existing technologies that would enable the project's objectives to be achieved, as well as the listing of other existing projects in this specific context. As to the market analysis, we began to define that ideally, the kit should be low cost, to facilitate the purchase and adoption by as many schools and users as possible. This led to a pre-selection of the technologies to be adopted and some of their essential characteristics.

To select the appropriate kits to be purchased and distributed to the schools, the market analysis included a comparative study according to a set of predefined indicators. The kits should include components such as an Arduino, LEDs, more than 3 types of sensors (i.e.: light, temperature, humidity, sound, air pressure, etc.), an accelerometer, and an OLED display. The kits should also be safe and suitable for being used by children between the ages of 5 and 10. Many of the kits and components analysed fell short, for instance, on issues related to robustness. When handled with little precision many would easily break and be redeemed useless. The team always envisioned the proposed activities as being done by the children and not by the teachers or another supervising adult. Last, but probably with a very high degree of relevance, the kit's overall price was considered one of the main deal makers. The budget assigned for purchasing over 900 kits could not be surpassed and, although some kits analysed were probably better solutions and included all the indicators listed, their price would imply a cut back on the number of kits which, in the long run, would put at stake the possibility of having at least 1 kit per student in classes of up to 28 pupils and setting aside at some backup kits for bits and spare parts.

The project ended up opting for the Grove de Arduino which guaranteed the majority of the requisites defined and came down to a price per unit of around 20€, including VAT tax. A true giveaway at the time if considered that, since 2020, prices regarding electronic components have skyrocketed. This kit, in particular, is now priced around 25€, a 20% increase over a period of a little under 2 years. This increase was not foreseen by the team, but the decision of buying additional kits for replacing damaged and lost parts turned out to be a good decision and one worth replicating in similar future projects. The Grove Arduino© kit, illustrated in figure 7, also provided some advantages such as its packaging, the fact that all the components were integrated into one kit and not bought separately and, as an added value, the fact that the kit was a product with a brand and reputation to uphold so customer service was guaranteed.

Figure 7. Grove Arduino© kit.



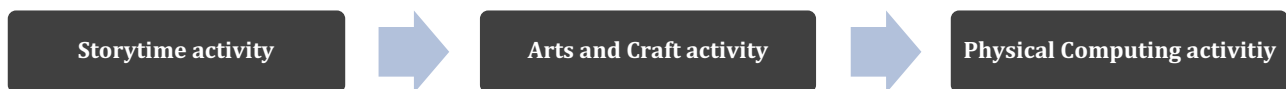
Source: <https://mauser.pt/>, 2022.

These kits were distributed to 32 public schools scattered across the municipality of Aveiro and each received 30 kits. Every box included 1 Grove Arduino© kit, 2 activity books, and activity printouts for each book.

4.2 The concept dimension

When reviewing the state of the art in the field and before designing the STEAM Kit the projects observed shared, in many cases, a common characteristic. There was a focus on providing the technology and tutorials on how to achieve certain results in a step-by-step approach with little or no concern with providing a narrative to glue together all these elements or to enable screen-free additional hands-on activities besides programming and plugging and unplugging components (Sullivan & Strawhacker, 2021). This meant that activities inherent would never go beyond the “if then else” mental map. If you did something, then another thing would happen and, if not done properly, order, etc, something else would happen or maybe not. With the concept proposed the team attempted to provide additional activities that, although correlated and linked as a whole, could in some cases be approached as an activity on its own. When looking at a closer level, the activities illustrated in figure 8, the more we progress into the activity sequence, the greater the dependency one activity has on the activity proposed before it.

Figure 8. The 3 activities included in each narrative.



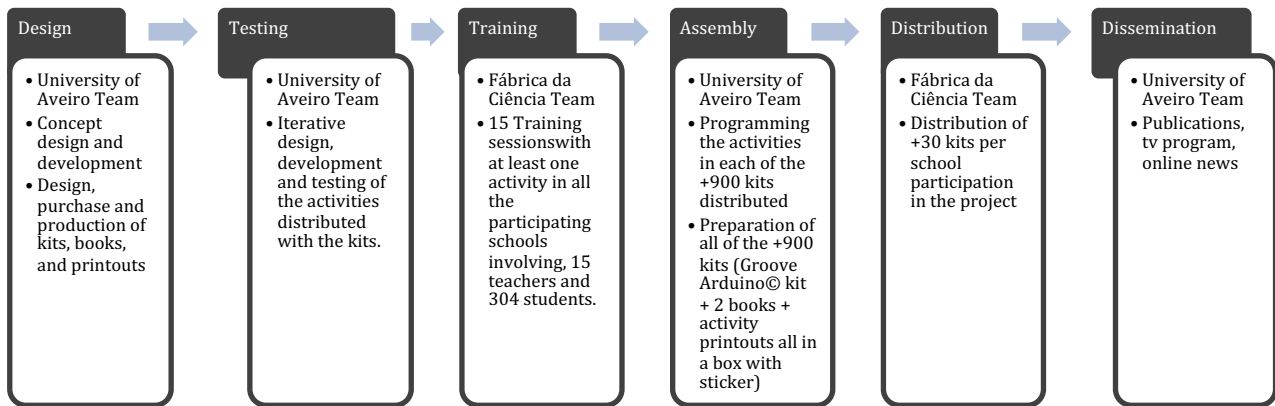
Source: Raposo & Vairinhos, 2021.

The activity story may be read and discussed without the need of carrying on to the next activities. However, this is not the case with the following activities. The storytime activity provides a narrative for the following activities. Nothing will keep students and teachers from undertaking the arts and craft activity, but they will be left wondering the storyline behind what they are being asked to do. If asked to conduct the physical computing activity students and teachers will leave wondering about what they are doing and what is the goal and context of what they are doing.

4.3 The practical dimension

As already mentioned in the introduction this project was developed with the Aveiro STEAM City project and involved, besides the University of Aveiro, our local Science Museum, also known as *Fábrica Centro Ciência Viva de Aveiro*, an interactive space open to the community and part of the national *Ciência Viva* Centres network, and a network of 30 schools in the Aveiro municipality. When discussing the practical dimension of the project it is worth outlining that the design, assembly, distribution, experimentation training and dissemination activities, developed over a 2-year period, involved each of these partners in different stages as illustrated in figure 9.

Figure 9. The stages, participants and task conducted during the project



Source: Raposo & Vairinhos, 2021

1. Design stage

The design stage, developed by the University of Aveiro team, was conducted over a period of 6 months and included a set of tasks such as the STEAM City Kit concept design; the creation of 2 original stories and their corresponding activities; the illustration of the 2 stories and activities with also original artwork created specifically for each story; the development of market research regarding each of the STEAM City Kit components (i.e.: Physical Computing kit, packaging, offset printing services for printer material - the books, activity printouts and box sticker); the purchase negotiation and overseeing of all the STEAM City Kit components according to strict public contract procedures; and, finally, the production overseeing of all the kit's printed material.

2. Testing stage

This stage of the project, in accordance with the adopted framework for innovation, included an iterative nature with various moments in which ongoing work regarding each activity would be tested by the development team, reviewed and adjusted. The COVID19 pandemic brought the whole project on hold for a considerable period due to the two nationwide lockdowns in 2020 and 2021. During the lockdowns and even after the harsher restrictions were lifted, other limitations in terms of social interaction and health regulations in schools and higher education institutions made it impossible to implement a participative design and testing strategy and, at the same time, meet the deadlines established by the funding programs. This issue will be further examined in the discussion section of this paper.

3. Training stage

The training Stage of the project included two sessions in which the team from the University of Aveiro prepared the team from Fábrica Centro Ciência Viva de Aveiro for the activities included in the STEAM City Kit s. These trainees would then take on the responsibility of coordinating and supervising the training sessions for teachers and the in-classroom activities. The team from the *Fábrica Centro Ciência Viva de Aveiro* was provided with 15 kits for the training sessions as well as digital versions ready to print out of the Tozé-Rex story, first story and activity designed for the STEAM City Kit.

The training sessions, coordinated and conducted by a team from the *Fábrica Centro Ciência Viva de Aveiro*, took place over a period of 3 months from May to July 2021. The sessions took place in primary schools within the Aveiro municipality, which from an administrative point of view are grouped into what according to Portuguese legislation is called *Agrupamentos*. Each *agrupamento* may be responsible for managing one or more kindergarten, primary or secondary public schools. The sessions were divided into two types: a training session for teachers and in-classroom activity sessions with teachers and students. The training session for teachers included 15 participants, had a 3-hour duration and varied greatly in the number of participants from each *agrupamento*. Participants varied from a single teacher, as in the case of the *Agrupamento de Escolas de Oliveirinha*, to a group of 7 teachers from the *Agrupamento de Escolas de Cacia*. The number of teachers per *agrupamento* that participated in the training session is presented in table 1.

Table 1. Number of teachers per agrupamento that participated in the training session.

Agrupamentos	Nr. of teachers
Agrupamento de Escolas de Aveiro	3
Agrupamento de Escolas de Eixo	2
Agrupamento de Escolas de Esgueira	2
Agrupamento de Escolas de Oliveirinha	1
Agrupamento de Escolas Dr. Mário Sacramento	6
Agrupamento de Escolas de Cacia	7
Agrupamento de Escolas José Estêvão	2
TOTAL	15

Source: Raposo & Vairinhos, 2021.

In this project, only the primary schools were involved and each of the in-classrooms activity sessions took up about 90 minutes of classroom study activity time. The number of participating teachers from each *agrupamento* was not coherent with participants who took part in the training sessions just for teachers for two reasons. In the case of the *Agrupamento de Escolas Dr. Mário Sacramento*, despite having 6 participants in the teacher training sessions 4 of these teachers did not teach 1st or 2nd-year students and 2 of them were only responsible for providing additional support for students with Special Education Needs. Except for this particular case, the rest of the vast majority of the agrupamentos also participated in the in-classroom activity sessions. A total of 15 activity sessions were held and involved a total of 304 students between the ages of 7 and 9. The number of participants per session varied between a minimum of 14 and a maximum of 24 students. The distribution of the number of sessions and students involved per *agrupamento* is presented in table 2.

Table 2. The number of in-classroom sessions per agrupamento and the number of students involved.

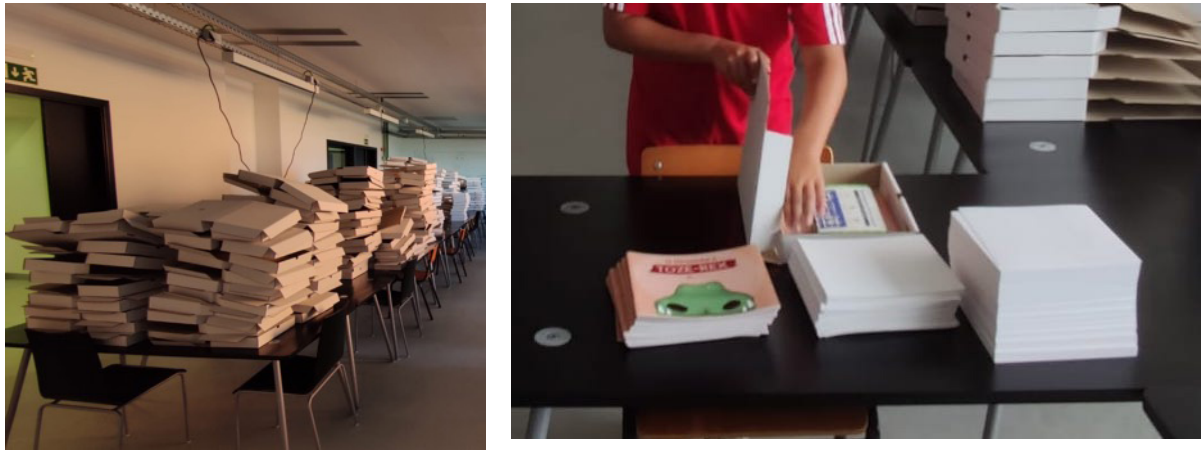
Agrupamentos	Nr. of sessions	Students involved
Agrupamento de Escolas de Aveiro	2	48
Agrupamento de Escolas de Eixo	4	58
Agrupamento de Escolas de Esgueira	6	102
Agrupamento de Escolas de Oliveirinha	2	45
Agrupamento de Escolas Dr. Mário Sacramento	0	0
Agrupamento de Escolas de Cacia	2	34
Agrupamento de Escolas José Estêvão	1	17
TOTAL		

Source: Raposo & Vairinhos, 2021

4. Assembly stage

Besides being tied to a short development and delivery plan, that got drastically shorter due to the pandemic and all its well-known implications, the STEAM City Kit project also had to make do with a challenging budget. It is sufficient to say that, for instance, the packaging and kit assembly were assured by members of the University of Aveiro team with, as the Beatles would put it, "a little help from our friends". During a couple of days, over 900 kits (Grove Arduino© + 2 books + activity printouts all in a box with personalized sticker) were prepared for distribution. The kits were boxed in an empty classroom at the Department of Communication and Art, at the University of Aveiro as seen in figure 10. In another room, pictured in figure 11, a team was preparing each Arduino that came with the Grove Arduino© Kit included in each STEAM City Kit.

Figure 10 – STEAM City Kit boxing.



Source: Raposo & Vairinhos, 2021.

Figure 11 – Grove Arduino© programming.



Source: Raposo & Vairinhos, 2021.

5. Distribution stage

After completing the assembly stage of the over 900 STEAM City Kits these were then handed over to the *Fábrica Centro Ciência Viva de Aveiro* team which took over their distribution across all the schools included in the project. The *Fábrica Centro Ciência Viva de Aveiro* team had scheduled other training sessions, within the context of the Aveiro STEAM City and Tech Labs Project, and each time they visited a new school they dropped off 30 STEAM City Kits at each of the 32 public primary schools in the municipality.

6. Dissemination stage

As for the dissemination stage of the project, it has been ongoing since the kits' distribution. The submission of papers to conferences and journals has been complemented with the short participation in a television program about research at the University of Aveiro and the project was highlighted in the University of Aveiro's *research@ua* magazine.

5. Discussion

The STEAM City Kit's project presented in this paper is, to a certain extent, still taking its first steps to the exploration of its full potential. Although the two stories and the activities provided with the kit are good examples of how the kits may be used there still are, as in any ICT education-related project, some frailties in need of discussion and further improvement. Much of what was achieved during the project's life cycle up to the distribution stage encompassed, despite its iterative development approach, some issues that were only fully visible during the training sessions conducted at the schools.

As already mentioned, all the constraints and restrictions derived from the COVID19 pandemic and the two lockdowns in Portugal played a very relevant role in the decisions made regarding the project, as well as its methodological implementation. The initial goal of developing a participative approach in the design and testing stage of the project was rendered impossible to implement at the time because the University of Aveiro team did not fully grasp how participative design could be implemented in a context where all the participants were at home and dealing, daily, with challenges unimaginable at the beginning of 2020. The positive thing is that, if ever presented with the same challenge, research and experiments conducted during these troublesome times have provided some guidance as to how to develop participative design efforts when presented with these extraordinary limitations.

The team is also aware of the fact that the time-consuming tasks, related to the purchase and production of the kits, would currently be even more difficult due to a widespread shortage of these types of resources, an increase in the price per unit and constant delays and other problems with product delivery. Just as an example the same company that provided the Grove Arduino© kit at little under 20€ per unit is now charging, depending on the quantities which are scarce, anywhere from 23€ to 25€ plus handling and delivery fees. This increase in prices could, eventually, be balanced with a wider search for other cheaper kits, with fewer sensors, or even a cut back in the number of kits purchased. Any of these solutions would, however, fall short when compared with the solution found, bought and included in the STEAM City Kits. When reviewing the training and in-classroom activities there is a sense that, despite some of the discrepancies that stand out between the number of participant teachers from some *agrupamentos* and the in-classroom activities, in general, there was an interesting level of interest from the network of public primary schools located in the Aveiro Municipality. With a total of 32 public primary schools grouped into 7 *agrupamentos*, some of the data collected indicated that:

- all but 1 *agrupamento* participated with both teachers and students in the training and in-classroom sessions;
- according to data from 2019 included in the Municipality Education Carta, at least 15 schools from a total of 32 took part in the activities provided;
- within a total of approximately 3061 primary students in the municipality of Aveiro, 304 had the opportunity to participate in the in-classroom activities.
- This data is already being used to outline upcoming follow-up initiatives to increase the number of participating schools, teachers and students.

The assembly stage of the project probably included one of the most unexpected results of the project. It was a relevant team-building moment that, besides achieving the results intended and meeting the distribution deadline, was also a great moment for exchanging ideas and brainstorming while programming the Arduinos, packaging the kits and putting stickers on over 900 boxes. The people involved have, since then, discussed ideas about where to take the project from here on.

The distribution stage of the project was, as already mentioned, conducted and supervised by the *Fábrica Centro Ciência Viva de Aveiro* team. 30 kits were handed into each of the 32 public primary schools in the municipality during visits related to other STEAM City activities. There is currently no data or feedback regarding the use of the kits in each school, but one of the follow-up activities currently being outlined is to visit and collect data regarding the kits' current use.

As for the dissemination activities linked with the project's results and future initiatives, there has been an effort to outline a plan which includes, besides the more traditional scientific publication of results, the goal of writing and submitting a proposal for an Erasmus + project with a network of other Higher Education Institutions and organizations interested in replicating and testing the STEAM City kits concept in their own countries.

6. Conclusions

Unquestionably, the development of digital competencies is currently considered one of the cornerstones for personal and social empowerment and growth. A quick online search will return thousands of legislation measures, actions and programs designed to contribute to the development of these competencies in a variety of teaching and learning contexts and environments. It would be highly presumptuous to assume that the work done with the STEAM City Kit project presented in this paper is ground-breaking and disruptive. The team involved is well aware that the project is, in fact, closer to a prototype stage of maturity than a final product stage. By acknowledging this reality, current and future activities related to the results attained up until now can easily be

outlined bearing in mind goals such as widespread methodological testing with larger samples of teachers and students; development of participative design efforts, including teachers, students and parents, regarding the development of additional stories and activities capable of exploring the full potential of the kit's concept and resources; and the elaboration and submission of a project proposal to national and European funding programs to develop further research based on the results already achieved.

It is believed that all the parties involved are well aware that the Aveiro STEAM CITY project has enabled the establishment of a multitude of Information and Communication Technologies infrastructures, both in the city of Aveiro and in the network of schools scattered all over the municipality in each of their Tech labs. The awareness may very well function as a trigger for motivating the further development of other initiatives linked not only to learning and teaching activities but also concerned with a variety of challenges set by the sustainable development goals presented by the United Nations. While many projects and initiatives in the Education field have opted for focusing on digital competencies linked with programming and robotics, sometimes overlooking students of a younger age, the project presented in this paper has chosen to explore concepts that include some of these concerns and try to combine them with reading and arts, crafts and creative activities (Sakon & Petsangsri, 2021; Chapman, Barton & Garvis, 2021). Much of what was achieved up to now although promising, still holds a world of opportunities and challenges (Fitzsimmons & Pearson, 2022) waiting to be explored, discussed and further worked on.

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