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Arts, Humanities, & Robotics in (STEAM) Education

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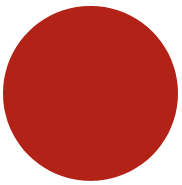

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Abstract

The purpose of this dissertation is to emphasise the articulation of three important themes that define our present and will define our future – Arts & Humanities, (STEAM) education, and Robotics. It hopes to facilitate the preparation of future generations for the 21st century society and economy, as well as to aid in the problem-solving of key world issues, and minimise the challenges posed by the relationship between humans and complex technology. The main goal is to understand the *ideal* way of including the 'A' in STEAM (K-12) education with Robotics, by also figuring out how European schools are implementing STEAM (with or without Robotics) and what experts and practitioners in these areas have to say on these matters.

In order to achieve such results, besides the robust literature review, sixteen experts were inquired, ten were part of the same panel on the Delphi Method questionnaire process, and the other six were interviewed according to the Critical Incident Technique.

Due to the relevance of the study's themes, this will be useful and resourceful for both fellow researchers and practitioners in these three areas.

As we go further into this evermore technological future for which we do not seem to be prepared for, the main problem is the dissonance between disciplines and the lack of their content's real-life applicability. STEAM and transdisciplinary knowledge have been gaining traction throughout the last years and have been proving themselves as suitable and successful educational techniques. The articulation between the Arts with the areas from STEM have proven to produce remarkable results. All areas *must*, while making sense, work together in order to provide students with the right tools, knowledge, and education to be successful not only in the global economy and job market of the 21st century, but in life too.

Keywords: Arts; Humanities; STEAM; Education; Robotics; Liberal Arts; 21st Century Skills; Transdisciplinary Knowledge.

"Tell me and I forget. Teach me and I remember. Involve me and I learn."

Benjamin Franklin

To my parents, my sister, & Anton

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To both FLUP and FEUP for having been my home for these extraordinary 5 years, where I grew not only as a student but also as a person.

Summary

Table summary

Abbreviations

AI – Artificial Intelligence

AR – Augmented Reality

CIT – Critical Incident Technique

DARPA – Defense Advanced Research Projects Agency

HRI – Human-Robot Interaction

RAND – Research and Development [organisation]

STEAM – Science, Technology, Engineering, Arts, and Mathematics

STEM – Science, Technology, Engineering, and Mathematics

VR – Virtual Reality

1. Introduction

1.1. Contextualization, framework, and motivation

This dissertation aims to shed light on several themes that not only define our present but will also dictate our future. Mainly, it focuses on the combination of the Arts and Humanities and STEM[1] in education, also known as STEAM[2]. It poses as a direct response to what is seen in today's world and hopes to aid in the preparation for the future, where transdisciplinary knowledge will be key and the problems between humans and complex technology, such as the branch of Robotics and Automation, must be minimised, if not totally eliminated.

Robotics, due to its ever more prevalent role in society and in today's technological world, is the chosen field of technology in order to produce a more palpable thesis. Additionally, it has been increasingly embraced by school curricula all over Europe and the world (Montero & Jormanainen, 2017; Perignat & Katz-Buonincontro, 2019), as it has become cheaper and easier to apply than other technologies such as Augmented Reality (AR) or Virtual Reality (VR). It has also gained adherence as a valid way to engage and prepare students for a potential future path in STEM (Ngamkajornwiwat *et al*., 2017, p. 457; Vu *et al*., 2019, p. 125), as well for a future life of growing collaboration and cooperation with intelligent machines. It is true that Robotics will continue to merge with the broad area of Artificial Intelligence (AI), however, in the moment's context and the scope of this dissertation, it is far more appropriate to refer to Automation and Robotics as a more tangible example to use in (STEAM) education than AI. This is due to the fact that regardless of the type of technology chosen, two of the main goals of STEAM implementation is the general demystification of technology and the consolidation of the human-technology interaction and relationship, since it is a topic that goes back to ancient times, already appearing in Egyptian, Babylonian, and Sumerian legends (Peters, 2020, p. 11) and is still one of the favourite subjects of science fiction novels and other forms of entertainment (Bartneck *et al*., 2020; Gnambs & Appel, 2019; Veruggio *et al*., 2016).

[1] **STEM** – Science, Technology, Engineering, and Mathematics
[2] **STEAM** – Science, Technology, Engineering, Arts, and Mathematics

When it comes to the Arts & Humanities, they are quite often seen as synonyms, although they are not technically the same. When most people think of them, they are referring to areas of the Social Sciences field such as: Philosophy, History, Anthropology, etc., as well as areas like: Photography, Design, and Poetry (Smith, 2015). Throughout this dissertation, whenever the Arts are mentioned, they are meant in a broader sense, also encompassing the Humanities, in a more holistic and Liberal Arts sense of the matter. As they cover a wide range of disciplines, Bakhshi *et al.* (2008, p. 1) and Bèrubè (2003, p. 15) emphasise how they vastly contribute to our ever-growing human knowledge, experience, agency, identity, and expression, therefore providing richness and diversity that can also be found in exact sciences.

Although STEAM can be applied to both K-12 and higher education, the theory written for both is fairly equal. The decision and need to beacon the target audience to K-12 education comes from the wish to make transdisciplinary education available and accessible to everyone, as not everyone enrols in university, along with the opportunity to reach the next generation in the most absorptive period of their lives. Additionally, the dissertation's time constraints, as well as the belief shared by many researchers that it is far better, easier, and more successful to apply STEAM and collect results in primary, middle, and secondary school, than in higher education (Lewis, 2015) contributed to this decision.

The motivation behind this dissertation is the belief in the value of versatility and exposure to interdisciplinarity, combined with the results gathered in multiple research projects about the benefits of a more holistic approach to education (de la Garza & Travis, 2019; Spector *et al*., 2015).

1.2. Problems, hypotheses, and research questions

As we go further into this increasingly heavier technological future for which we do not seem to be prepared for, the main problem seen in literature and in practice is the lack of education's application in real-world problems. As for STEAM education, the previously mentioned combination of the Arts and STEM, a common and repeated undervalue of the 'A' component is observed. It seems as if it is only present to make STEM more accessible and attractive to the youth, in order to encourage them in pursuing one of these areas (Sciences, Technology, Engineering, or Mathematics) and, consequently, preparing them

for the future job market (Bevins, 2011; Hobbs, 2019; Land, 2013; Lewis, 2015; Madden *et al*., 2013; Taylor, 2016). Nevertheless, there is some recognition for the skills one can garner in a Liberal Arts education and how merging it with a STEM one can lead to a more holistic educational approach and to extraordinary results (Bevins, 2011; Conradty & Bogner, 2018; Marmon, 2019; Spector *et al*., 2015; Taylor, 2016).

This dissertation's contribution aims to fill this gap. It focuses on the 'A' in STEAM and proposes a thesis on how its equal inclusion can be done a context with Robotics. It wants to understand what kind of contribution the Arts and Humanities can give, alone and included in STEM, as well as what is the current state of both STEAM education and (educational) Robotics in Europe, specific K-12. It is likewise important to gather and triangulate the opinions, theories, and experiences of key-people and stakeholders in these areas, the experts and/or practitioners, on how the 'A' should be included in this context.

Just like Bevins (2011) stated in his pioneer article, *STEM: Moving the Liberal Arts Education into the 21st Century*, the future is bright for both the Arts, broadly, Humanities, and STEM, but not as separate, and independent areas. They *must* work together in order to provide the future generations with the right tools, knowledge, reflection, sensitivity, and education, so they can take advantage of great opportunities, as well as create them, so they can be successful not only in the global economy and job market of the 21st century, but in life too (Bevins, 2011, pp. 12-13).

Therefore, this dissertation's thesis, which has not yet been the sole target of an isolated research, will be useful and resourceful to both fellow researchers and practitioners in the STEAM and education fields, as well as educational robotics.

This dissertation seeks to answer three research questions. The main research question is:

What is the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?

This query can only be answered after responding the following auxiliary questions:
How are European schools implementing STEAM (with Robotics)?
What do experts and practitioners say on the current inclusion of the 'A' in STEAM and on how it should be included?

1.3. Research methodology

Given that little is known about the *ideal* way of including the 'A' in a STEAM educational curriculum with Robotics, emphasising the equal role of the component, the chosen methodology is qualitative and highly exploratory. In addition to the substantial literature review, two research methods were selected to assess the experts' and practitioners' opinions and experiences regarding the research questions and beyond – the Delphi Method and the Critical Incident Technique. The first conducted via a series of subsequent questionnaires and the latter via semi-structured interviews. With the information collected in the literature review and via the two methods, the goal was to produce new knowledge based on their triangulation.

1.4. Structure

This dissertation is divided into four main chapters.

The first chapter pertains to the introduction of the theme studied and it is fractioned in four subchapters. The first subchapter (1.1.) offers a concise contextualisation and an overview of this study's framework, as well as the motivation behind it. It talks about the three major themes – Arts & Humanities, (STEAM) education, and Robotics – and briefly explains the thought process of approaching this research. The second subchapter (1.2.) focuses on the problems recognised both in theory and practice, as well as some hypotheses regarding the main subjects in question. It also presents the research questions and the problem(s) aimed to be solved. The third subchapter (1.3.) regards the research methodology and the research methods chosen to carry out this research. I succinctly explain and justify my decisions, giving a preview on how this investigation was conducted.

The second chapter concerns the literature review. It begins by introducing (2.1.) the key themes that make up this dissertation and provides three individual subchapters (2.2., 2.3., 2.4.) to each one of them. Therefore, a more concise and clear critique is done of what has already been studied and written on these matters. This is followed by a subchapter (2.5.) focused on the relationship between the three main concepts of the investigation. The literature review chapter end with the conclusion (2.6), where the most important information is synthesised and where it is established the theoretical framework for the present thesis.

Given the plurality of subjects and research methods of this dissertation, the third chapter corresponds to the methodology and the presentation and interpretation of the results. It is split into three subchapters. The first subchapter (3.1.) pertains to the Delphi Method and is separated into three subsequent subchapters: one (3.1.1.) pertaining to the background of the procedure, another one (3.1.2.) concerning the data collection plan and the data collection itself, and the last one (3.1.3.) relating to the presentation and discussion of the results, i.e., the consensus reached. The second subchapter (3.2.) pertains to the second study conducted, the Critical Incident Technique. This one is also divided into three successive chapters: 3.2.1., concerning the research method itself, 3.2.2., relating to the data collection plan and the collection itself, and 3.2.3., where the results are showcased and examined. The last subchapter (3.3.) of the third chapter regards to the triangulation between all sources of information – literature, Delphi Method, & CIT. It begins with a small introduction recapping the aims this dissertation and the methods to getting there, followed by three subchapters that correspond to each one of the research questions (3.3.1., 3.3.2., 3.3.3).

The fourth and final chapter is the conclusion of the study, where the whole process is summarised and where the final notions are given about the knowledge produced, the study's limitations, its utility, and potential future work. This final chapter is followed by the list of references and the annexes.

2. Literature review

2.1. Introduction

The present chapter concerns the literature review carried out in order to understand the current stances on the dissertation's major themes, as well as comprehend their evolution and impact. Over the course of the dissertation, almost 100 readings were done, however, only 58[3] were considered relevant. Of these 58, 33 are journal articles, 14 are books, 2 are reports, 6 are book chapters, and 3 are web articles. Their publishing date ranges from 1950 to 2021. Pertaining to their themes, 32 delve into Robotics, 34 into (STEAM) education, and 6 into the Arts and Humanities. There are some that definitely explore more than one theme. Some readings revealed themselves to be more pertinent than others, however, all were extremely valuable in understanding the context and the framework of these key-areas, as well as their development throughout the years.

All three major topics – the Arts and Humanities, (STEAM) education, and Robotics – have been relating to each other historically for quite some time but have become more apparent in the last few years. This can be explained by our changing society, the shifting of our values and the widening of our horizons by what recent discoveries and new technology has enabled us to achieve. Since our very beginning on Earth, we have had a drive to understand the world around us. We have been expressing ourselves since our cave days, through painting, rituals, dances, myths, etc. We have had the passion to understand what it is not clear to us by acknowledging life's complexity. And, since our primal days, the Arts, in a broader sense, have been part of who we are (Ibarra & Sommerstad, 2019).

Our current times are characterised by contradictions and transformations. Science and Technology allow us to live longer, provide us with instant and global communication, and revolutionised production by introducing Robotics and Automation to the lines of manufacture. Nevertheless, issues have arisen despite all this progress. Problems such as climate change, pandemics, violence, loss of biodiversity, among others, have been demanding ever changing solutions, in order to accompany society and its evolution. Despite the demand, there has been a lack of response or incapacity to appropriately respond to these matters, and this has been traced back to, mostly, the compartmentalisation of both

[3] Check Annex nr. 7.5. for the complete list of readings.

scientific and professional knowledge (de la Garza, 2019; Ibarra & Sommerstad, 2019). This new Information Age has shifted what we have known so far, from the market to the culture, as well as education (Bevins, 2011). It has become vital that we embrace the changes and try to make our contribution and participation more meaningful through better problem-solving skills, which will stimulate innovative and intricate solutions (de la Garza, 2019; Madden *et al*., 2013). That starts with education, not only because today's students are tomorrow's adults, but also because education has been crucial for the advancement of societies, not only technologically, but also socially. Despite the cyclical and typical problems that affect the world, such as crisis, wars, epidemics, etc., discoveries and innovations have continued, and have been allowing us to better our quality of life and its expectancy (Bevins, 2011). So, in order to go along with the world's evolution and progress, education needs to be dynamic and respond to the students' needs, as well as prepare them for the future that awaits them (Bevins, 2011; Conde *et al*., 2021).

Thus, educational institutions must be able to adapt to the current state of the world and provide students with the competencies necessary to strive in the future job market and the future society (Conde *et al*., 2021; Dito, 2013). The commonly known STEM education has been the sole focus over the last decades due to the highly technical skills necessary to succeed in the current technological world (Dito, 2013). However, STEAM has become even more prevalent in the last few years because it offers students a lot more than that (Land, 2013), it offers the promise of a transdisciplinary education. The integration of the Arts, the 'A', in STEM enhances the development of transdisciplinary skills such as analytical thought, critical and creative thinking, curiosity, among others (Hobbs, 2019; Perignat & Katz-Buonincontro, 2019). These are some of the so called liquid skills, or better known as 21st century skills (Trilling & Fadel, 2009), that along with verbal communication and active listening and learning, will enable students, the adults of tomorrow, to "adapt to a fluid working landscape throughout their lives; to prepare for jobs that currently do not exist" (Peters, 2020, p. 90). These are the necessary tools to tackle the current issues we face and the ones that have not yet appeared. There is a need for us humans to rethink our role in confronting traditional values and morals, and do the necessary changes to adapt and overcome key-issues, and that is where Art, in a general sense, has always played a big role (Ibarra & Sommerstad, 2019). Adding the 'A' to STEM, converting it into STEAM, will be imperative so humanity will be able to grow and provide for their future generations in terms of skills and innovations (Hobbs, 2019). Still, this addition has not been easily done, as it is often incorporated just for the sake of it, or as a way of making STEM more appealing and

accessible, and not as providing a genuine contribution (Conradty & Bogner, 2018; Herro & Quigley, 2017; Land, 2013; Spector *et al*., 2015).

The position of protagonist that Robotics and Automation has enjoyed in the last few years comes from the fact that a growing number of robots are operating not only in industries, 2.7 million worldwide as of 2020 (IFR, 2020), but in domestic and military sectors as well (Borenstein & Arkin, 2016). As a matter of fact, many roboticists, as well as renowned scholars of History of Science and Technology, have regarded the 21st century as the 'Age of Robots' (Veruggio & Operto, 2008). So, it is obvious that its inclusion makes way into education, specifically STEM and STEAM education, because it can be an opening for other technologies, and helps the articulation between all subjects, as the future of innovative thinking goes beyond STEM, and is connected to the Arts and Humanities (Coombs *et al*., 2021).

2.2. Arts & Humanities

As previously mentioned, the Arts and Humanities include a very broad array of fields, such as History, Literature, Philosophy, among others. They contribute to the expanding knowledge on human experience and existence, and they vary from other areas of scientific practice, by making fragmented and vague evidence comprehensible (Bakhshi *et al*., 2008). This way, they remind us of our ability to interpret and see the world through different lenses (Kagan, 2009; Smith, 2015). The Arts excite our will to act first upon ourselves and then go beyond towards others (Heidegger, 1977), because it not only enlightens but also improves our emotional experiences, therefore positively impacting our well-being, and, consequently, our society as a whole (Blockley, 2019).

The Renaissance was a particular time in History that highlighted not only the Arts and Humanities, but also their articulation with the Natural Sciences. This can be seen in, for example, Leonardo Da Vinci's (1452-1519) path as an artist incredibly immersed in Science. He modelled the perfect human form and its proportions in what became known as the *Vitruvian Man*. He became known for the relationship he created between the Arts and the Sciences. He believed the study of the latter made him a better artist, because he understood better his subjects. This could be said for other notable individuals, such as Isaac Newton (1642-1726/27), who besides being a scientist was also a theologian and author; John James Audubon (1785-1851), who was both an ornithologist and a painter; Samuel

Morse (1791-1872), who was an inventor and a painter; Johann Wolfgang von Goethe (1749-1832), who, among other things, was a poet, scientist, and amateur artist; Lewis Carroll (1832-1898), a writer, photographer, mathematician, inventor, and Anglican deacon; and Beatrix Potter (1866-1943), also a writer, an illustrator, natural scientist, and conservationist (Ibarra & Sommerstad, 2019).

Yet, as Kagan (2009) explains in his book, as the years went by, the Arts and Humanities, as well as their articulation with the Natural Sciences, became less and less relevant and common. With the Scientific Revolution and the triumph of the Industrial Revolution, i.e., the rise of technical and tangible application of knowledge, the confidence and role the Arts played so far was severely weakened. The over compartmentalisation and specialisation of all areas of knowledge, although helpful, also hindered the relationship between different areas of expertise, which contributed to the continuous rise of the Sciences and the decline of the Arts and Humanities.

Despite their decline in "popularity", their value, contribution, and utility, never ceased to be pertinent. Bakhshi *et al*. (2008) in their article delve deep into this subject, highlighting how the Arts and Humanities provide a foundational insight on the impacts of change in a society, because they pursue the understanding of the human experience, from its identity to its expression, through elements such as language, artefacts, literature, traditions, and so on. Therefore, their help broaden our knowledge and produce new ideas and concepts that can be directly applied in innovating. Some, like Dumitru (2019), even argue that critical thinking is not possible without an appropriate humanistic education, or without, at least, some contact with the Arts and Humanities. Because one of the roles of the Arts is to create or find meaning in things and meaning can only be found if there exists creative and critical thinking. In contrast, Bèrubè (2003) states that, in a tangible way, the Arts and Humanities will not meaningfully contribute towards the growth of society in the fields of Business, Science, and Technology. Yet, he recognises their unquantifiable value of teaching us what it is to be human and to be part of a common society and culture. They might not produce precise theories or palpable innovations like the Sciences do, as Bèrubè (2003, pp. 27-28) exemplified with the discovery of the cosmic microwave, but their knowledge contributes more directly towards the cultural well-being and self-identification of a society, because they concern things that are a lot more personal and relatable. There is also a conversation on whether we should demand that the Arts and Humanities deliver something more concrete, like the Sciences, or on whether we should let them continue their legacy of human and skill development (Bèrubè, 2003).

Despite all the contradicting theories and opinions, it is defended by scholars that the Humanities carry out a plethora of crucial functions. Such as Kagan (2009) defends in his book: "They remind the society of its contradictions, articulate salient emotional states, detect changing cultural premises, confront their culture's deepest moral dilemmas, and document the unpredictable events that punctuate a life or historical era. The books, poems, plays, and films that contain these ideas help the public find a balance between the benevolent and self-destructive consequences of their illusions so that hopefully each can create an ideal worthy of effort" (p. 231). With this in mind, the Arts and Humanities offer an extraordinary framework and context where the Sciences, in a broader sense, that is including Engineering and other areas of scientific knowledge, converge and inhabit within.

The dichotomy between the Arts and Sciences is also quite an ancient query and has translated into the education realm. The discussion over which is more relevant, a liberal education or a technical one, has persisted for over 2.000 years. As Bevins (2011) explains in his article, the Liberal Arts education is historically referred to as the Arts, Humanities, and Sciences, whereas the Technical Education pertains to the Industrial Arts and Vocational Training (p. 10). The reason why a Liberal Arts education is more appealing is because it sustains the potential to contribute to the formation of global citizens who think and create solutions for the world's biggest issues, by emphasising analytical thinking, argumentation, and an active participation in the community and overall society (Nussbaum, 2004 in Gogus, 2015, p. 278). This stems from the intrinsic philosophy of the liberal education that, according to Gogus (2015), liberates the mind, fosters judgment, and encourages both personal and intellectual growth and stimulates social responsibility (pp. 277-278). Therefore, it stimulates transdisciplinary skills that are not only important to thrive in a professional environment, but in personal and societal too.

In the last few years, the value and utility of the Arts and Humanities has been more recognised as it has been proven by empirical research that an arts education fosters students' creative and soft skills (Perignat & Katz-Buonincontro, 2019). Therefore, in accordance with today's societal and technological landscape, the future of the Liberal Arts education, therefore of the Arts and Humanities, is tightly connected with the STEM areas, which has originated into STEAM, which is the inclusion of the Arts component in the STEM fields (Marmon, 2015).

2.3. (STEAM) Education

According to Montero & Jormanainen (2017), the term STEM appeared in the early 90s by the National Science Foundation of the United States as an acronym for Science, Technology, Engineering, and Mathematics. Despite discussions about the range of its meaning, it became vastly used when referring to the areas of Natural Sciences and Technology (p. 34). In an educational setting, STEM is meant to concern the integration of these four different fields into a cross-disciplinary subject (Liliawati *et al*., 2017; Dugger, 2010 cited in Marmon, 2019a). Predominantly economic reasons are behind the heavy relevance of STEM in schools. This is due to the desire of preparing students for future careers in STEM, as the demand for technical and hard skills has continued to grow more and more. Consequently, this stimulated the further integration of technology in schools, first with computers, and more recently with Robotics, which has been proven to help not only in knowledge acquisition, but also in increasing students' interest and test scores (Vu *et al*., 2019). Nonetheless, STEM has been taught separately from the Arts and Humanities (Liliawati *et al*., 2017; Stroud & Baines, 2019), despite the fact that the relationship between the Natural Sciences and the Arts is secular, dating back to brilliant innovators such as Leonardo Da Vinci (Sullivan *et al*., 2017), who was previously mentioned as articulating his art with the study of Science, more specifically the anatomy of the human body. However, nowadays, the situation is not much different, as "it is estimated that Nobel laureates in the sciences are seventeen times likelier than the average scientists to be a painter, twelve times as likely to be a poet, and four times as likely to be a musician" (Pomeroy, 2012 cited in Sullivan *et al*., 2017, p. 233). This is likely rooted in the fact that all these areas share the same curiosity, creativity, and will to understand what we do not yet comprehend (Sullivan *et al*., 2017).

STEM, which has been around for thirty years, has been the focus of education because it offers students the opportunity to develop their technical skills which are in high demand at the present and will continue to be in the future (Conde *et al*., 2021; Hobbs, 2019; Marmon, 2019), due to the technological growth we have witnessed in such short amount of time. But recently, it has been demonstrated that STEM knowledge will not be sufficient to strive in both the professional and personal framework of the future. There is a certain pressure in creating curricula that prepares students to thrive as a society in the future by converging the scientific knowledge with Technology but also with the Arts. The main goal is for students to be able to apply their expertise to real-world problems and produce creative

and innovative solutions. The workforce of the future, i.e., the students of today, will need to be equipped with the right tools in order to strive in the 21st century economy and society (Maeda, 2013; Spector, 2015). These tools, labelled the 21st century skills, vary depending on the source, but their basis revolves around four key points: communication, collaboration, critical thinking, and creativity (Christensen & Knezek, 2015, p. 19). That is why, once again, we turn to the articulation between the Arts, the liberal education, and the Sciences, the technical training (Hobbs, 2019).

STEAM – Sciences, Technology, Engineering, Arts, and Mathematics – is a fairly recent concept, as it appeared in the late 2000s, early 2010s. Its origins vary in literature. Some say it appeared, as a new form of pedagogy, in 2007, during the American for the Art-Nation Policy Roundtable discussion, in the United States, as an answer to the need of prompting students' interest and skills in STEM and, simultaneously, inverting the decline observed in Arts education not only in the US, but in the whole world (de la Garza & Travis, 2019; Perignat & Katz-Buonincontro, 2019). Other sources say the term STEAM surfaced in 2010 through Harvey White, founder of Qualcomm[4], who considered that the STEM field lacked skills and habits rooted in creative problem-solving (Marmon, 2019). What is clear is that, initially, the STEAM movement was primarily led by the Rhode Island School of Design (RISD) (Spector, 2015; Sullivan *et al.*, 2017), a private Art and Design school in the United States, and in particular by John Maeda, who was president of the school between the years of 2008 and 2013, right around the time STEAM emerged.

As the acronym itself suggests, STEAM is an extension of STEM by including the Arts component (Liliawati *et al.*, 2017). The 'A', however, means different things to different scholars, which reflects in its practices (Liao, 2019). The way to secure that the inclusion of the 'A' is not reductive or for mere embellishment, is by thinking about it as something whole but wide, that is, the Arts in a broader sense. The Arts can encompass not only the Visual and Fine Arts (Sculpture, Painting, Crafting, Graphic, etc.), but also Communication (Literature, Advertising, Multimedia, etc.), Performative Arts (Film, Theatre, Music, Dance, etc.), and the Humanities (History, Philosophy, Anthropology, etc.) (Liliawati *et al.*, 2017). The purpose of STEAM and of including the Arts in a thoughtful way is to prepare students with the necessary literacy in the fields of STEM, highly demanded nowadays and that will continue to lead the way in our global economy, but also

[4] Qualcomm – An American multinational corporation that focuses on "inventing breakthrough technologies that transforms how the world connects, computes, and communicates" (Qualcomm, 2021).

in the fields of the Arts and Humanities, which help craft the person as a human being and as part of a community (Yoon & Baek, 2018). It is not only important that future generations continue to produce solutions to relevant world issues, but that these solutions are created faster, are more economic, sustainable, and long-lasting. This can only be achieved by citizens that understand the connection between the different areas of knowledge, and who are able to apply their expertise to the formation of new, cutting-edge, innovative, and creative solutions (Dito, 2013; Lewis, 2015; Manera, 2020; Marmon, 2019; Montero & Jormanainen, 2017; Yoon & Baek, 2018). Simultaneously, STEAM, as largely K-12 initiative, aims to "bridge the interdisciplinary creativity, and innovation found in both art and science", therefore creating a well-rounded curriculum (Lewis, 2015, pp. 262-263), which goes beyond preparing students for their future work life, and prepares them to play an active role in our civilization (Perignat & Katz-Buonincontro, 2019; Stroud *et al*., 2019).

One of the most noticeable weaknesses of STEM is the lack of gender and racial diversity (Manera, 2020) in both top roles (CEOs, chief-investigators, etc.) and mere participants ("regular" employees). Overall, although it is a changing paradigm, the world is run by white men. By understanding that this model will not be sustainable for the future and the world will gain much more from all types of diversity (racial, gender, sexuality, religious, etc.), including cross-curricular and transdisciplinary knowledge, STEAM has gained even more traction (Sullivan *et al*., 2017). However, it is easier said than done. STEAM is still a fairly recent strand of education and therefore lacks clarity (Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019). This leads to ambiguity and a plethora of different interpretations, and well as to criticism (Quigley *et al*., 2019). The one that stands out the most is concerning the inclusion of the 'A'. The move from STEM to STEAM is not, or it should not be, the mere addition of the Arts to STEM education (e.g., embellishment of a given technology), or even the use of the Arts as a way to teach STEM in a more accessible and attractive way (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015). This turns out to be useless as it does not provide any contribution of substance, thus defeating the purpose of STEAM in the first place and highly undervaluing the importance and the role of the Arts and Humanities. Nonetheless, as mentioned in the previous subchapter, there is recognition from many scholars for what the Arts and Humanities can do not only for students but for individuals in general (Bakhshi *et al*., 2008; Bèrubè, 2003; Dumitru, 2019). In literature regarding STEAM education different meanings have been attributed to the letter 'A'. One

very common meaning attached to the 'A' component in STEAM is creativity. Creativity is often seen as the process of creating something new and original and this concept is intimately linked with critical thinking and reflection, because fields in the Arts and Humanities easily foster environments conducive to generate critical thinking, creativity, and the reflection over meaning (Dumitru, 2019; Ghanbari, 2014; Lewis, 2015; Marmon, 2019; Spector, 2015). It has been proven to be beneficial to nurture creativity in students, because it enhances their abilities in overall thinking, in coping with stress, in enhancing their self-awareness, that is, their overall social and life skills (e.g., teamwork, communication, confidence, etc.), which will positively impact their community and, consequently, the world (Madden *et al*., 2013, p. 542). Still, it feels as if it is not taking advantage of the full scope the Arts and Humanities can offer. That is why many other intellectuals see the 'A' as something much broader, a spectrum, that also includes the Liberal Arts essence, Languages, Social Studies, Music, Culture, History, and so on (Liao, 2019; Perignat & Katz-Buonincontro, 2019; Sullivan *et al*., 2017).

From a psychological point of view, the reason behind the positive effects so far attested for the integration of the Arts into STEM (STEAM education) is the fact that students become more confident and self-aware (Marmon, 2019; Montero & Jormanainen, 2017; Vu *et al*., 2019). This is because the Arts are very similar to the Sciences in the sense that their process is based on experimentation and discovery (Johnson, 2019). Within the artistic education realm, students have the opportunity to articulate their learning process with decision-making (Land, 2013), something that is often lacking in schools' curricula and in education in general. This is frequently tied with Design-Thinking, which is usually understood as a creative problem-solving process (Henriksen *et al*., 2019; Liao, 2019). It is scientifically proven that "When an individual is taught a single concept, the brain creates neural pathways connecting the concept to his or her experience. The more access points or neural pathways established, the greater the chance of retention and recall" (Land, 2013, p. 549). That is why stimulating the brain not only with techniques such as the Design-Thinking process, but with the overall Arts integration into STEM, enables students to explore one single concept from different stand points (Land, 2013), which contributes to their computational thinking, which will, consequently, allow them to employ their knowledge in a way that is adaptable to each situation, professional or not. This is backed up mostly by specialists in Cognitive Psychology and Neuroscience, as they can attest for the neurological effects that the Arts and Humanities training can have in enhancing humans' intellectual process (Ghanbari, 2014; Marmon, 2019). Thus, the role of the Arts in

STEM is to prepare better humans, not just for future professional landscapes, or a specific industry, but also for a personal too (Marmon, 2019).

With what concerns Europe and STEAM education, there have been multiple initiatives over the last few years in order to stimulate its integration in schools' curricula, especially in projects that target public schools, so the already existing disparities do not grow even bigger. The projects' main focus have been the development of interdisciplinary competencies such as creativity, digital literacy, and critical thinking (Manera, 2020, pp. 103-104). However, transforming or even adjusting the current educational system in each country from the traditional molds to a new improved way is not easy (Christensen & Knezek, 2015; Conde *et al*., 2021). Every country, and even every region and school, has its own context and needs (Babaci-Wilhite *et al*., 2019), which makes the implementation of STEAM much more specific and confusing. That is why research and experimenting is extremely important, in order to better understand what works and what does not. This dissertation hopes to bring some light into these subjects by talking to educators who can help this progression via their experience and knowledge. Lately, this subject has been receiving more and more attention, and it is where this dissertation fits, especially within EU educational policies, but there is still much more trail to blaze. The full potential of STEAM and its practices has not yet been realised (Christensen & Knezek, 2015; Ryan *et al*., 2019). STEAM as a new form of schooling will never become static. There will always be improvements, adaptations, reformations, and so on. The future of STEAM education must be flexible and sensible to what is going on in the world at a given time so it can deliver what is expected of it (Marmon, 2019).

2.4. Robotics

The term 'Robotics' was coined by Isaac Asimov, known writer of the 20th Century and professor of Biochemistry at Boston University, in the 1940s. As Bartneck *et al*. (2020) describes in their book, Asimov wrote primarily about the relationship between human beings and robots, with themes revolving around: "How much people will trust robots?", "What kind of relationship can a person have with a robot?", "How does our ideas of what is human change when we have machines doing humanlike things in our midst?", and so on (p. 6). When he wrote them, they were considered to be Science Fiction, however, nowadays, this is our reality. These ethical questions, among many others, are at the centre

of Human-Robot Interaction (Bartneck *et al*., 2020; Kaplan, 2015; Veruggio *et al*., 2016). The concept of a 'Robot' is, nonetheless, older. It is present in the History and culture of many societies, going back thousands of years, as well in recent Science-Fiction narratives (Bartneck *et al*., 2020; Peters, 2020). Although most cultural notions of robots may not be technically realistic, they have paved the way for people's expectations and reactions towards them (Bartneck *et al*., 2020, pp. 11-12).

Ever since robots stopped existing just in fiction and transitioned to the real world, one of the first reactions was to contemplate about its relationship with human beings (Bartneck *et al*., 2020). It is the first time in the History of our world that we are replicating intelligent and autonomous entities. This requires the scientific community to examine this situation very carefully, as Robotics is "a unique combination of many scientific disciplines, whose fields of applications are broadening more and more, according to the scientific and technological advancements" (Veruggio & Operto, 2006, p. 3).

Regarding the question "What is a Robot?", there are many different approaches. Veruggio & Operto (2006, p. 4), in their article, offer four different answers. The first one regards robots as simply machines, with no conscience, free will, or any type of autonomy that would be able to superimpose human beings. The second regards robots as having ethical dimensions, dealing with them not just as an addition to man, but as a way that helps mankind continue to distinguish itself from other animals. The third one considers robots as morel agents, not in the sense of having free will and a conscience, but in a way where they can perform any action whether it is for good cause or not. The last perspective sees robots as the evolution of a new species. They will not only have autonomy and a conscience, but they will surpass humanity in both moral and intellectual dimensions. This way, machines will be better than us and, depending on the opinion, we will be better because we created them (J. Storrs Hall cited in Veruggio & Operto, 2006, p. 4).

For thousands of years, we have been relying on tools and machines to increasingly eliminate labour and unnecessary work. This highly contributed to our economic success and progress since the Industrial Revolution, and especially since the introduction of computers and automatic machines in the 20th century. The 21st century will be, for the first time, an era of coexistence between humans and intelligent machines (Veruggio *et al*., 2016, p. 2136).

Robotics is not necessarily a new science, as it is often seen as a branch of Engineering, but some see it as the convergence of multiple areas. Like Veruggio *et al*. (2016) state in their chapter, Robotics originates from Mechanics, Automation, Electronics,

Computer Science, Cybernetics, and Artificial Intelligence. Nevertheless, it relates to other fields such as Physics and Mathematics, Logic and Linguistics, Neuroscience and Psychology, Biology and Physiology, and Anthropology and Philosophy (p. 2138). It is important not to neglect the humanistic aspect of technology. Different cultures and religions differ in opinions concerning the intervention of artificial machines in areas that are intimately human, such as reproduction, privacy, etc., and carry different values that will affect how complex technology will be implemented in a given context. That is why, in 2002, Gianmarco Veruggio, an Italian roboticist, coined the term 'Roboethics' (Veruggio & Operto, 2008). He saw the importance in regarding diversity (gender, ethnicity, cultural, etc.) and articulating it with the technical side of Robotics in order to assure the best integration and relationship. So, it is not only about the Ethics of robots, but also about the Ethics concerning the robots' designers, manufacturers, and users (Veruggio *et al*., 2016). HRI, that is, Human-Robot Interaction, also exists as a discipline and its focus is, like the name suggests, on the interaction between humans and social robots. This brings up both technical and design challenges related to appearance, behaviour, abilities, and so on. From a psychological perspective it allows the study of human affect, intellect, and conduct when confronted with social agents that are not human (Bartneck *et al*., 2020). Asimov (1950), in his celebrated book *I, Robot*, delved for the first time into questions like these and came up with the notorious *Three Laws of Robotics*:

1. *A robot may not injure a human being, or, through inaction, allow a human being to come to harm.*
2. *A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*
3. *A robot must protect its own existence as long as such protection does not conflict with the First or Second Law*

Handbook of Robotics, 56th Edition, 2058 A.D.

The relationship between humans and autonomous machines has been reflected about for centuries, appearing in world literature based on legends and myths, in scientific and moral essays (Veruggio *et al*., 2016; Veruggio & Operto, 2006, 2008). There are different portrayals of such machines, depending on the cultural context. For example, in classic European literature, the topic of rebellions of this type of machines is recurring, however, in Japanese culture, machines are seen as always beneficial and friendly to humans. That is why the reflection proposed by Human-Robot Interaction is so critical and needed (Veruggio & Operto, 2006). Additionally, Robotics and robots have, in general, fascinated

authors, scientists, and the masses for decades (Gnambs & Appel, 2019). Robots have been depicted in all formats, from books, to movies, and computer games, in all ways, from positive perspectives, to world-destroying ones (Atanasoski & Vora, 2019; Gnambs & Appel, 2019; Veruggio *et al*., 2016). These depictions have helped the formation of humanity's opinion and knowledge of robots, which often leads to bias formation as a consequence (Bartneck *et al*., 2020).

Nowadays, Robotics is much more widespread than imagined, not only in numbers but also in areas of application. Robots are now, not just in automotive industry, but also in healthcare, education, sex industry, and in our homes (e.g., cleaning robots such as *Roomba*) (Gnambs & Appel, 2019; Szczepanowski *et al*., 2020). As indicated in the introduction to this chapter, as of 2020, 2.7 million robots are operating worldwide in the most varied sectors of life. In the industrial sector, China continues to take the lead, but European countries are included in the top 10 of Annual Installations of Industrial Robots, with Germany in 5th place, Italy in 6th, and France in 7th (IFR, 2020). Because Robotics has become ever more prevalent not only in Europe, but in the whole world, there are questions that nations have to think about. Questions such as the fear of unemployment, the level of collaboration and interaction between humans and intelligent machines, the guidelines for its implementation in schools, the rules for companion robots, the potential usage of robots in the military (e.g., killer-robots or robot-soldiers), and so forth. Along with this, it is necessary that society in general accepts the continued diffusion of new technology (Gnambs & Appel, 2019), that is why the European Union is making sure to keep up to date with current events and is dedicating money and resources in order to prepare for an increasingly technological future. They have produced, for example, the Green Paper, which is the first European attempt at bringing together Robotics and legal communities. This paper focuses on the most important legal hurdles regarding robots' autonomy, that is, if they are to be considered legal subjects, with agency, or legal objects, seen as property and physical entities. In this paper, robots are perceived as being a mix of both. Articulated with the Green Paper is the White Paper, which aims to look at Robotics by putting humans first, which will result in policy making that will have unbreakable boundaries that will eliminate the risk of mankind jeopardising itself (Rommetveit *et al*., 2020). This is all leading to what experts, such as the World Economic Forum, call the 'Fourth Industrial Revolution', where production and even programming will be able to be done by the machines themselves (Atanasoski & Vora, 2019). The COVID-19 pandemic has also shown the weaknesses of globalised supply chains, and Robotics and Automation have been considered to help level

productivity, as well as relieve some jobs of unnecessary human interaction (IFR, 2021b; Pasquale, 2020).

Since the early 2000s, Robotics has gained traction among teachers because it is seen as a helpful tool to develop cognitive and social skills for students of all ages by supporting their learning not only in the STEM subjects, but also in more artistic and humanistic ones, embracing an interdisciplinary education. Some believe Robotics are introduced in school curricula in order to prompt students into STEM. However, this has yet to be proven to work. Any problem concerning Robotics is multi-layered, which can be daunting for teachers and students, but can stimulate all parties to bridge the knowledge acquired from all different subjects and applicate it in a way that helps producing the solution (Nunez, 2016). Numerous studies have already proven that a robot-based education enhances academic success in subjects associated with it (Alimisis, 2013; Coombs *et al*., 2021; Manera, 2020; Veruggio *et al*., 2016; Yoon & Baek, 2018). This, among other things, is due to the fact that educational robotics fosters an environment where students can interact with what they are studying or learning and where they can deal with real-world problems. Concurrently, the number of educational robotics initiatives in Europe has been growing, from workshops, to conferences, courses, tournaments, and so on, despite the fact that the integration of Robotics in European school curricula is still very residual. Obstacles such as the lack of time, money, and guidelines are the reason behind this. Robotic activities are time consuming, and the cost of its equipment is often out of most schools' budget, along with the fact that most teachers are not trained and do not know how to put into practice interdisciplinary teaching. This leads to schools not properly preparing students with the right tools (the previously mentioned 21st century skills) to strive in the world they live in now, let alone the world of tomorrow (Alimisis, 2013).

The landscape of educational robotics consists mainly in pre-programmed, prefabricated robots, which limits students learning process by restricting their creativity and critical thinking. However, kits, the most common educational format, give teachers some guidelines and practical ideas of how to incorporate Robotics in the classroom, which is, as mentioned before, one of the biggest obstacles to the implementation of Robotics in schools (Alimisis, 2013; Nunez, 2016; Sullivan *et al*., 2017).

Some criticism appears in regard to this integration. Some say there is not enough quantitative research that supports how Robotics enhances students' learning successes, others emphasise the idea that Robotics in schools should not be the end point for improving learning, but rather seen as another tool that articulated with others (curriculum, activities,

etc.) will improve the students' learning experience (Alimisis, 2013; Pasquale, 2020). However, most scholars are enthusiastic about it, as long as it is done in a way that makes sense. As Damaševicius *et al*. (2018) expresses in their work, by including Robotics in education, we are presenting students a hybrid tool that converges Art and Technology, which will properly show them how the STEM subjects correlate with the more artistic and humanistic ones. This is essential because it demonstrates the interaction between technology, humans, and, ultimately, society, by providing an enriched learning environment (p. 138) (Bartneck *et al*., 2020).

As Gogus (2015) states in her work, the use of promising technologies is key to be successful in life. So, understanding these said technologies and developing the necessary technical and humanistic skills is even more important in order to instigate students' conceptual comprehension, problem-solving techniques, and critical thinking skills (p. 287). In order to gauge positive perspective towards these complex machines, it is important to work towards opening the minds of the masses by putting them into contact with what seems to be abstract technology (Bartneck *et al*., 2020). This will also help minimise inequality (racial, gender, etc.), by expanding the benefits of the technological growth and by making sure it reach all kinds of people (Kaplan, 2015). We need to take advantage of the fact that we are still at the very beginning of what some scholars call the 'Age of Robots' (Veruggio & Operto, 2008), and that we need to establish initial conditions, because, as Kaplan (2015) foresees, as the time goes by, the autonomous machines will continue to be progressively more autonomous, necessitating less and less human supervision, and some of them may even start designing their own heirs, to whatever purpose they are conditioned to think it is best (pp. 206-207). Other questions like the use of robots for military purposes also need to be thought of as they are the central focus for Ethics in international law (Pasquale, 2020). Some campaigns and conferences have surfaced to halt this specific usage of robots and ponder its consequences. However, specific guidelines are yet to be imposed (Perignat & Katz-Buonincontro, 2019). One trend that continues to be central regarding the future of Robotics is cooperation, not only with the technology itself, but also between peers, corporations, countries, and so forth (Bostrom, 2014; Kopacek, 2019). This, besides aligning with the historical facts concerning human-robot interaction, is crucial given that Automation continues to rise all over Europe as five European countries are part of the Top 10 Most Automated Countries in the World: (1) South Korea, (2) Japan, (3) Germany, (4) Sweden, (5) Denmark, (6) Hong Kong, (7) Chinese Taipei, (8) USA, (9) Belgium, and (10) Luxembourg (IFR, 2021a).

2.5. The ‘A’ in STEAM & Robotics

More and more initiatives are being carried out and implemented around the world concerning the integration of the Arts and Humanities in STEM, especially in education, as well as incorporating Robotics as a means of enhancing this articulation. However, as previously discussed, the ‘A’ is often added to STEM just for the sake of it or as a way of teaching STEM in an easier and accessible way (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015), which undervalues the component and what it has to offer, not only alone but articulated with other areas of knowledge. It is clear to everyone that the future will certainly focus on STEM areas (Conradty & Bogner, 2018; Herro & Quigley, 2017; Land, 2013; Spector *et al*., 2015), nevertheless, what is also clear is the rapid need to prepare our society with the right tools to strive in the future, the 21st century skills (Taylor, 2016; Trilling & Fadel, 2009). What is also quite obvious is that the articulation between all areas of knowledge is not a new and original concept. The Renaissance and geniuses like Leonardo Da Vinci, probably the best known to put STEAM into practice before this term even existed, and Galileo Galilei, among others who came afterwards, proved how beneficial and natural it is to move across the spectrum of knowledge without barriers (de la Garza & Travis, 2019; Henriksen *et al*., 2019; Hobbs, 2019).

Just as Ibarra & Sommerstad (2019) reflect in their chapter, Art and Science have always been intimately linked throughout History (p. 151), and they complement each other rather than being hierarchically ordered as it is perceived today (Bakhshi *et al*., 2008). Many scholars highlight the similarities between the Arts, in a broader sense, and the Sciences. The same authors (Ibarra & Sommerstad, 2019), emphasise the parallels in perception, methodology, symbology, and execution. They reflect on how the Arts ask eternal questions and how the Sciences try to answer them; how artists and scientists are both investigators, observing the world around them, sensing that there is something beyond what we know and see. “This is what inspires awe and wonder, which inspires ideas and hypotheses, which inspires experimentation and movement” (p. 151). This is what historically has made us progress, the curiosity to learn and experiment, and early scientific discoveries reveal that Science is not as rational or objective as it seems. It is through these quests to better

understand the world we live in that we consequently get closer to understanding ourselves, therefore, creativity and self-awareness are both part of the Arts and Sciences (Ibarra & Sommerstad, 2019). Da Vinci himself wrote the 'Principles for the Development of a Complete Mind', which entail the study of the Science of Art, the study of the Art of Science, the development of our senses (especially our vision), and the realisation that everything is connected to everything else (Ghanbari, 2014, p. 1). As previously stated, the separation between the Arts and the Sciences happened only after the Renaissance, as the scientific knowledge grew exponentially (Blockley, 2019). Today, we start to see again the beauty and the benefits of not isolating areas of knowledge but articulating them in ways that are both natural and sensible. As de la Garza & Travis (2019a) describe in the introduction of their book, the Sciences and the Arts can benefit from one another: "Science can benefit from philosophical, ethical and aesthetic insights, in order to better deal with issues of uncertainty and contingency" and "Conversely, arts and humanities disciplines can be energized by scientific understandings of dynamic processes, technological innovations and the process of exploration and discovery" (p. 2). Specialization is important and necessary, however, if there is no collaboration between peers and areas of expertise, the gap between intellectuals and non-specialists, i.e. the masses, will continue to grow (Einstein, 2006). This comes from the fact that it is imperative that society in general knows the basics of what is discovered and how it affects us as a whole, as well as what are our key issues that need immediate solutions. This is what Einstein (2006) considers to elevate society and renew its strength. Kagan (2009) shares similar views in his book *The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century*, stating that the current position of the general society towards scientific knowledge is unsure. This is due to the lack of understanding of general scientific concepts and methods, as well as having a general suspicion over scientists' true intentions, and how knowledge changes and evolves, which can fragilize its validity to some (p. 58). Nonetheless, the Sciences contribute to our material and physical well-being by helping us understand natural phenomena. On the other hand, the Arts and Humanities allow us to comprehend our society and what produces historical changes, by also giving us a glimpse of how our morals and values are born and how they impact our life. Hence, there is an obvious necessity for the Arts and Sciences to collaborate and mutually elevate one another in order to provide the best kind of knowledge and a more updated and aware society (Kagan, 2009).

Globalization has changed the necessary skills to strive today and, especially, in the world of tomorrow. Skills like critical thinking, problem-solving, communication, and

collaboration are in high-demand for workers in all types of industries (Conradty & Bogner, 2018; Damaševicius *et al*., 2018). This, of course, has also affected education, as it is training the future generation for a world that will be long gone. This is why many experts have the same opinion that a transdisciplinary education is the best holistic approach to education (Quigley *et al*., 2019), because students of today are quite distinct from the ones of the past decades. They are surrounded by technology and need to understand how the knowledge they are acquiring can be applied to the real world. They also need to be actively engaged in the learning process and not just the recipients or spectators of it, thus reiterating the need for a fluid education without barriers where disciplines communicate and share their knowledge and practices (Bevins, 2011).

As previously indicated, the Arts and Humanities and Robotics have been articulated in many different forms into what is now known as STEAM education. Still, it has also been stated how this articulation and incorporation might be done most of the times superficially (Montero & Jormanainen, 2017). There is still a lot of exploration to be done and an adaptable pedagogical framework to be developed. The primal allure of integrating the Arts and also using Robotics is because it is seen as enhancing students' cognitive, social, emotional, physical, and artistic development, which fosters creativity and permanent passion for learning (Damaševicius *et al*., 2018). In Europe there has been some efforts in order to change the schools' curricula, to better integrate current technologies, and foster the learning of STEM competencies, such as programming, Physics, electronics, etc. What has been proving to be more difficult is the integration and articulation of the Arts and Humanities with the skills mentioned above. Still, the efforts continue to grow and research continues to be done in these particular areas as a means to better guide the implementation (Montero & Jormanainen, 2017; Perignat & Katz-Buonincontro, 2019). Some of the already known trials of STEAM implementation with Robotics go along the lines of: unifying Robotics and Theatre (Montero & Jormanainen, 2017); through low-cost robot competitions (Conde *et al*., 2021); and via pre-packaged robot kits (Nunez, 2016). One of the emerging technologies used to enhance the Robotics incorporation is 3D printing, whose usage is dual. The first facet relies on the influence of the artistic process from the point of view of design, and the second one is that it delivers a palpable artifact that reflects the knowledge acquired from the activity in question. Other technologies emerging are Augment Reality (AR) and Virtual Reality (VR) (Marmon, 2019).

Regarding the inclusion of the 'A' in STEAM with Robotics, some tangible examples are provided in the literature concerning this subject. One way to better implement STEAM

with Robotics without neglecting the 'A' is by understanding that Robotics go beyond technical fields into areas such as Philosophy, Ethics, Theology, Biology, Physiology, Neuroscience, Law, and so forth (Kopacek, 2019). This is important to stress, because learning about Robotics will not only be important for students who want to become engineers but also to all the others who do not. Robotics has to be seen as a gateway for the infinite world of complex technology, with which all of us will have to co-habit with regardless of our area of work (Veruggio *et al*., 2016). However, it is important to make decisions well based, and avoid the use of technology just for the sake of it, and the same goes for the Arts part. Inclusion has to have meaning, purpose, and value, not just superficial or ornamental dimensions (Bush & Cook, 2019). Manera (2020), highlights the Reggio Emilia Approach, which "has been proposing educational robotics in playful environments since the 1980s", and offers children scenarios where they can explore distinct ideas and propose their own hypotheses, which allows Robotics to be mixed with other disciplines, therefore stimulating the STEAM learning experience (pp. 105-107). And finally, authors like Bush & Cook (2019) describe in their chapter a project carried out with fourth-grade students which was inspired by another smaller student who missed a portion of her arm. They started the process by synthesising the different areas of STEAM they needed, followed by the designing, and building of the prosthetic arm. This project which emerged from an authentic and meaningful problem, motivated students to empathise with others who are different and bring that compassion to the activity by articulating it with the knowledge acquired and applied (pp. 25-30).

2.6. Conclusion

With all this information in mind, it is clear that the three basic concepts of this dissertation – Arts & Humanities, (STEAM) education, and Robotics – are articulated among themselves not only recently, but historically for centuries, as reflected in geniuses such as Leonardo Da Vinci, Isaac Newton, and so on (Ibarra & Sommerstad, 2019).

Regarding the Arts and Humanities, we have seen how they had quite an important role up until the Renaissance, and how they intermingled with the Natural Sciences intuitively. Still, even after its "decline", their value and utility remained the same. Bakhshi *et al*. (2008) highlighted how the Arts and Humanities contribute to the expansion of our knowledge of human experience and existence, which as Kagan (2009) and Smith (2015)

underline helps to remind us of our capability to comprehend and view the world through different eyes. And Heidegger (1977) adds how they excite our will to not only act for ourselves but for our society as well, because just as Blockley (2019) states, they enlighten us by expanding our emotional capabilities, our empathy, thus positively affecting our well-being, and, consequently our community.

STEAM, an updated and more inclusive version of STEM, which surfaced in the late 2000s, early 2010s, is considered to be the future of education because of the experiences and competencies it provides its students not only for their professional future, but for their personal one too (Marmon, 2019; Perignat & Katz-Buonincontro, 2019). The difference is in the inclusion of the 'A', meaning the Arts, in the areas of STEM. However, as seen in literature, there is much confusion regarding what the 'A' stands for (Perignat & Katz-Buonincontro, 2019). In order to prevent what happens too often, i.e., the inclusion of the Arts in a very reductive and superficial way (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015), the 'A' should be perceived in a general sense as encompassing both the Arts (Fine Arts) and Humanities. It is evident that both the Arts and Humanities and the Sciences (STEM) need to collaborate and intermix in order to provide people, specifically students, with the right tools to strive in the 21st century global economy and in their lives (Maeda, 2013; Spector, 2015).

As for Robotics, some believe we have entered the 'Age of Robots' (Veruggio & Operto, 2008). The subject of the relationship and interaction between human beings and autonomous machines is secular (Veruggio *et al*., 2016; Veruggio & Operto, 2006, 2008), but has become more important since the Industrial Revolution and recently with the increased rise of the use of Automation all around the world. This has prompted the reflection concerning Ethics (Roboethics) and human-robot interaction, as it is crucial, we have a prepared society to deal with the ever-expanding growth of complex technology. That is why educational robotics as seen a rise in the last few years, as it promises, and delivers, to foster conditions where students can interact with what they are learning and apply it to real-world problems (Alimisis, 2013). Nonetheless, its implementation in schools is still flawed. There are still lack of funding and specific guidelines that steer educators and all key-people in the journey that is modernising and updating the educational system (Alimisis, 2013; Nunez, 2016; Sullivan *et al*., 2017).

It is clear, though, to all scholars, that technology is and will continue to be a protagonist in our world and society, therefore, it is necessary to prepare students with the

right tools and education so they can succeed (Dito, 2013; Lewis, 2015; Manera, 2020; Marmon, 2019; Montero & Jormanainen, 2017; Perignat & Katz-Buonincontro, 2019; Stroud *et al*., 2019; Yoon & Baek, 2018). There is still a lot of consideration and research to be done in these fields in order to perfect its articulation and implementation. Still, Robotics is seen as the best way to incorporate complex technology in schools without the need to buy overly expensive material or equipment, thus acting as a door for other technologies, such AI. This will help prepare students, the future of our society, for the even more heavily technological world of tomorrow, by equipping them with both technical and humanistic tools, and stimulating their sensitivity and critical sense of being (Lewis, 2015).

Having in mind this synthesised knowledge gathered for the present dissertation's literature review, the theoretical model that depicts the articulation between the three main concepts of this research is the following:

- With the soar of complex technologies, such as AI, AR, VR, Robotics, etc., competencies have drastically shifted and today's youth needs to be equipped with the 21st century skills in order to prosper (Land, 2013).
- Robotics are changing the way we live, work, and operate in society (Veruggio & Operto, 2008). With its expansion, as it is the same for most technologies, Robotics require transdisciplinary knowledge and it is crucial that one does not neglect the humanistic facet of the equation (Bartneck *et al*., 2020).
- If things do not change, especially how we educate our youth, unemployment will be a serious issue, but not because of a scarcity of jobs. Instead, the competencies requested for the available jobs will evolve much quicker than our society and our educational systems can keep up with (Kaplan, 2015). That is why it is crucial to start the change and modernisation now.
- Bringing the Humanities to communicate as they should with Robotics will help accelerate the process of better implementing it, as well as securing the inclusion of all members of society, of different cultures, race, gender, sexuality, etc., so it generates a well-balanced civilization and economy (Kopacek, 2019; Pasquale, 2020; Spector, 2015).
- STEAM education is the future, because it creates the perfect combination of all areas of expertise and fosters the perfect environment for students to garner the right tools and acquire the right expertise in order to produce innovative and creative solutions to real-world issues, as well as instil in them the notion of lifelong learning, something that will be crucial to continuously adapt to the

changes in economic and societal landscapes (Bevins, 2011; Marmon, 2019; Quigley *et al*., 2019).

- The ‘A’ in STEAM should be perceived as the Arts in a broader sense, so as to avoid its trivial or reductive inclusion (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015). The Arts are so much more than their visual facet and can richly contribute to the world and the formation of well-rounded citizens (Kagan, 2009).
- If we continue to separate the STEM areas from the humanistic and artistic ones, we will be jeopardising our future, putting our next generations at a disadvantage (Marmon, 2019). The future lies in the communication and articulation between technical education and a Liberal Arts one (Bevins, 2011).
- COVID-19 has had a powerful impact in our society with negatively, however, it has also brought some positives outcomes. It has shown us even more the usefulness and importance of Robotics as well as opened our minds to practices and new ways of living that we had not considered before (work from home, the value of technology and how important it is to have its literacy, etc.) (IFR, 2020).

3. Empirical Studies

Given that this research does not aim to determine something quantitative or even experimental, the qualitative research process seemed to be adequate for its iteractivity and flexibility (Crescentini & Mainardi, 2009, p. 433). The three research questions were framed in a way where they reflected a need understand the main themes of this dissertation, that is:

- How European schools are implementing STEAM and harmonising it with Robotics;
- What key-people in these areas – Arts & Humanities, (STEAM) education, and Robotics – have to say on the inclusion of the 'A' in STEM;
- And, finally, what would be the *ideal* way of including the 'A' in a STEAM (K-12) curriculum regarding Robotics.

Since this dissertation's themes are not a very well explored context, it seemed pertinent to gather information outside of the already existing literature on these subjects. Because STEAM is a fairly recent concept, as it originated in the late 2000s, early 2010s (de la Garza & Travis, 2019; Marmon, 2019; Perignat & Katz-Buonincontro, 2019), and it is the main subject of this study, it was relevant to understand and gather the opinions and perspectives of experts and/or practitioners who have first-hand experience working with this. Thus, two research methods were selected in order to collect this information: the Delphi Method, via a questionnaire process, and the Critical Incident Technique, via semi-structured, one-on-one interviews.

The decision to articulate two different research methods is justified by the fact that it provided more than one way of gathering information, with the participation of more experts and practitioners, and allowed for a more diverse collection of data, as the two methods were carried out in distinct ways.

Additionally, in a qualitative research process it is crucial to conceive a good data collection plan taking into account the goals, theoretical framework, and the research questions of the investigation. Given the iterative nature of this research, it was paramount that the data collection plan was well formulated and executed, not only in order to conduct a rigorous and founded assembly of data, but also to validate the resultant findings (Crescentini & Mainardi, 2009, p. 434).

Due to the time sensitive nature of this dissertation and the need to rely on experts and their immediate availability, it was imperative that this was taken into account during the planning process. Thus, both methods were applied in essence, although some adjustments were made in order to fit the period given to complete the study, the objectives of the research and the research questions.

3.1. Empirical Study I

3.1.1. Delphi Method

The Delphi Method was initiated by the RAND Corporation[5] during the Cold War as a preparation for potential national security threats (Wounderger, 1991 cited in Lund, 2020, p. 929). It was created as a way of gathering many experts on foreign policy and national security, and researchers quickly realised the potential of this method as a way of forming a consensus among a group of distinct experts (Lund, 2020), where privacy was one of its key factors (Dalkey & Helmer, 1963; Okoli & Pawlowski, 2004). The adoption of the method as a legitimate research method began in the 1970s (Lund, 2020), and nowadays, it is used in almost every field and it is "considered to have an acceptable level of validity" (Lund, 2020, p. 930).

According to Lund (2020, p. 931), the classical steps of a traditional Delphi Method process are:

1. Identification of the research problem;
2. Development of the research questions;
3. Selection of the experts (participants in the study);
4. Administration of the first round of the study;
5. Synthesisation of the responses;
6. Presentation of the synthesised responses to the respondents;
7. Administration of the second round of the study;
8. Synthesisation of the responses;

[5] The RAND Corporation, in which RAND stands for research and development, "is a[n American] research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous" (*About the RAND Corporation*, 2021).

9. Presentation of the synthesised responses to the respondents;
10. Continuation of this process until a pre-planned number of rounds has been reached, or the respondents have reached a consensus;
11. Analysis of the responses from each round;
12. Distribution of the findings.

The focal point of this method is "to obtain the most reliable consensus of a group of experts" on a given subject (Dalkey & Helmer, 1963, p. 458). It is considered to be more advantageous than other methods for its non-confrontational aspect. It is, therefore, more propitious to instigate individual thought and prevent influence and intrusion of the opinions of others (Dalkey & Helmer, 1963). This method is typically carried out through a series of questionnaires intermingled with controlled feedback from the participants (Okoli & Pawlowski, 2004).

The participants of the study are, according to the literature, chosen based on their knowledge and expertise on the subject in question. The mindful and prudent selection of the experts is, perhaps, the most important part in the Delphi Method process. Ideally, they should not be nominated based on their personal relationships with the researcher (Avella, 2016; Hasson *et al.*, 2000 cited in Lund, 2020), as well as they should not be the obvious specialists of a specific field (Lund, 2020). Consequently, the selected experts should be the ones with "the most intimate knowledge and experience with the topic" (Baker *et al.*, 2006; Welty, 1972 cited in Lund, 2020, p. 931).

The process of selecting the experts is quite complex and lengthy. Firstly, according to Okoli & Pawlowski (2004, pp. 20-21), a Knowledge Resource Nomination Worksheet should be prepared, known as KRNW, which helps in the organisation of the experts' profile before identifying them. So, we begin with pinpointing relevant disciplines or skills, as well as organisations, and literature. This way there is clear idea of what to look out for. The next step is to populate the KRNW with names, after which it is established the first contact with the experts nominated in the sheet. However, this first contact is not to invite them to join the study, but for them to provide the names of other experts. After accumulating a hefty list of potential experts, one has to rank them based on their qualifications by creating separate sublists. It is only after this ranking is done that the invitations begin. They should move according to the ranking done in the sublists and the ideal amount is between 10 to 18 experts per panel. Depending on the subject in question, more than one panel can be formed (Okoli & Pawlowski, 2004).

Following the invitations and the acceptances, the data collection process begins. The procedure to administer the questionnaires is, once again, intricate, and long. They can be administered a couple of ways, given that email, fax, and the web, are the most common (Okoli & Pawlowski, 2004). According to Delbecq *et al*. (1975, cited in Okoli & Pawlowski, 2004), if carried out this way, the data collection phase can take from 45 days to 5 months.

As stated by Okoli & Pawlowski (2004, p. 24) and adapted from Schmidt *et al*. (2001), the questionnaire administration process can be divided into three phases: (1) brainstorming, (2) narrowing down, and (3) ranking. The first phase, the brainstorming, corresponds to the initial collection of information. The first questionnaire is sent on the same day that an expert agrees to participate in the study and its questions represent the study's research questions. After all the experts have responded, the researcher synthesises the responses and sets aside the ones that are identical. If necessary, the synthesis should be done via categories so when returned to the experts it is easier to comprehend. These categories are for presentation purposes only and not for analysis. The second questionnaire is sent in order to validate the synthesis resulting from the initial one and gives the experts the opportunity to confirm their answers or change/give additional information. Moreover, the second questionnaire will question the experts on two things: on how accurately their answers have been interpreted, and on their opinion regarding the synthesised information. They will be able to help further refine the information gathered and hopefully contribute to the growing consensus. The second phase, which pertains to narrowing down information, begins with the deployment of the third questionnaire, where the experts will be presented with the consolidated list of information gathered so far, which will expectantly help its definition and cancel out the bias. The fourth and final phase, corresponds to ranking the chosen factors, that is, to reach a final consensus among what is relevant to answer the study's research questions. The fourth questionnaire is sent, and each expert has to rank the synthesised information so far from the least to the most important and explain their decisions. At this point the level of consensus has to be calculated. According to Okoli & Pawlowski (2004, p. 26), the best way to measure non-parametric rankings is using Kendall's W coefficient of concordance. Kendall's W is a value that ranges from 0 to 1, where 0 indicates no consensus, and 1 indicates absolute consensus. The value $W = 0.7$ has been pinpointed as suggesting a strong agreement, therefore, a strong consensus. Unless this number is reached, the fourth questionnaire has to be repeated. As different studies have different time constraints, there are other factors that allow the stopping of the Delphi process: (1) $W = 0.7$, which, once again, designates an appropriate level of consensus among experts; (2) The number of

questionnaires sent out has reached the pre-planned number; or (3) The ranking of the last two consecutive rounds are not significantly different (Okoli & Pawlowski, 2004).

The analysis of the gathered information is done along with its collection, as it is a highly iterative process. Still, the final consensus is the final result of the whole process, and it is what usually is used in the study.

This method was chosen for the present research because it allowed the inquiry of key-people in the areas being studied, that is, the Arts & Humanities, (STEAM) education, and Robotics. Given the current state of the world, still battling COVID-19, it is the perfect group method as it does not require for neither group meetings or in-present meetings (Okoli & Pawlowski, 2004, p. 18). Finally, it is suitable because this dissertation seeks to identify an ideal, "in other words, blaze new territory rather than work an area that is already well-defined" (Lund, 2020, p. 932), regarding the main research question: *What is the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?*

3.1.2. Data collection

Taking into account the 11 classical steps of a traditional Delphi Method process (Lund, 2020), the first two – identification of the research problem & development of the research questions – were already done as they were part of the initial stages of this dissertation. The third step, the selection of the experts, as explained above, is perhaps the most crucial activity in the whole method and it is usually very lengthy and complex. The data collection itself, that is, only the questionnaires, usually takes from 45 days to 6 months to complete, without considering the planning prior to that. Given the short amount of time to do and write this dissertation, it was imperative to modify and adapt most of the remaining steps. Of course, decisions were made along the way to ensure that the rigour and usability of the data collected were not compromised. In order to restrain the data collection into the time frame appropriate for the development of this research, three questionnaires were planned to be administered. Three was considered to be the perfect number to obtain a certain level of consensus, given that three iterations occurred, and it fitted nicely into the work plan and deadlines. If by the third questionnaire there was still time, perhaps further iterations could take place. However, this method was the last one to be concluded and it took much longer than planned. As consequence, Kendall's W was not calculated as the questionnaires themselves were simplified and very targeted towards the research questions. This is justified by the necessity to maintain rigour and collect data according to the Delphi

Method, by simultaneously cutting down extra tasks or overcomplicated steps that did not necessarily made sense for the present research. The decision was then made that after three questionnaires, the Delphi Method questionnaire process would be complete.

The same justified liberties were taken when selecting the experts. As stated before, this stage is considered by scholars to be the most important (Lund, 2020) as it will directly affect the quality of the data collected. Knowing that the KRNW would be impossible to do in such a short time, research was done in order to gather names for potential experts. This research was based on the readings conducted for the state-of-the-art part of the process, and a list of 93 possible experts was created. Nonetheless, from almost the very beginning of the implementation of the Delphi Method, it was known that I would not be able to religiously follow the traditional way of doing it. The biggest hurdle and reason for this is the time constrictions, not only for the dissertation itself, but also because it depended on experts' speedy availability to participate in the study. The experts contacted were the ones who were easier to contact and who responded more promptly.

The profile of the experts is what made them suitable or not to participate in the study as it was detrimental to maintain the rigour and quality of the data collected. Therefore, the experts contact, and even considered, were all specialists and/ or practitioners in the areas of the Arts and Humanities, (STEAM) education, and/or Robotics. The fact that all have experience and still work in the educational landscape allows for a more timely and accurate understanding of the matters in question.

Table 1 – Delphi Method Experts' Profile

Expert	Profile
1	• From Belgium • STEAM coordinator at a Belgian semi-private school (K-12)
2	• From Finland • Principal at a Finnish school (K-12)
3	• From Germany • Teacher at a German school (K-12) • Works with Robotics
4	• From Portugal • STEAM coordinator at a Portuguese private school (K-12)
5	• From Belgium • Teacher at a Belgian semi-private school (K-12)
6	• From Romania • Programme director at a Romanian community foundation
7	• From Germany

	• Principal at a German school (K-12)
8	• From Spain • Teacher at a Spanish public school (K-12) & teacher trainer
9	• From Finland • Teacher at a Finnish school (K-12)
10	• From Finland • Principal at a Finnish school (K-12)

After securing the recommended minimum of ten experts (Okoli & Pawlowski, 2004), the data collection itself begun. As previously explained, according to Okoli & Pawlowski (2004), the first step of the Delphi Method data collection process is the administration of the first questionnaire. The first questionnaire was crafted using Google Forms and it was sent on the same day the experts agree to participate in the study and it pertained to the initial collection of elements. The contact was established via email and the questionnaires were sent attached to it. In the first stages of the study, meetings were scheduled with the experts that accepted to participate in order to clarify any doubts and further explain the purpose and intent of the dissertation. Due to time constraints on both parts, the contact with the last four experts was done strictly via email as a means to speed up the process. This initial survey[6] consisted in questioning them regarding the research questions, and asking them an additional question that would help frame their opinions:

- What do you consider to be the 'A' in STEAM?
- What is your personal and professional opinion on how the inclusion of the Arts and Humanities in STEAM **is** done?
- What is your personal and professional opinion on how the inclusion of the Arts and Humanities in STEAM **should** be done?
- What do you consider to be the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?

The experts were able to answer freely, being only limited by the maximum 32.000 characters that Google Forms permits. The questionnaires were sent between April 15th and May 21st, 2021, and this stage was finalised on June 7th, 2021, when the questionnaire finally reached the ten answers. Undoubtedly, it was a lengthy process, because it was the first interaction with the experts, which, due to their busy schedules, in some cases, took longer to establish. However, with this previously in mind, the deadlines for the Delphi Method

[6] Check Annex 7.1.1. for the complete Google Forms with the First Delphi Questionnaire.

data collection were planned accordingly, i.e., knowing the next stages would be much quicker, as the contact with the specialists was already established, they were more familiar with the subject, and their task became more important, but increasingly easier and less time consuming.

After the gathering of the ten initial answers, the data was analysed (read subchapter below), and the second questionnaire[7] was crafted and deployed, precisely on June 7th, 2021. This stage pertains to the validation of the categorised list of factors taken from the answers to the first inquiry (Okoli & Pawlowski, 2004). So, the questionnaire consisted of repeating the same four questions sent on the first one, but instead of allowing the experts to write freely, they had to select the options they felt were best. The options were the factors consolidated from their answers to the first questionnaire.

Experts were able to choose more than one option. Along with the email, the experts were sent a copy of their answers to the first questionnaire. This stage allowed for the specialists to validate their answers from the first iteration (by reviewing their answers and reiterating it, or not, by selecting the corresponding options), to refine their answers (answer differently from the previous questionnaire), and to give further input regarding each question via the "other option" field). Additionally, at the end of the questionnaire, the participants could contribute with further pertinent ideas that were not consider previously, in the "Write here any additional information you would like to share that does not fit into the questions above (OPTIONAL)".

Experts were given a full week, from June 7th to June 14th to complete the questionnaire, in order to comply with the dissertation's time constraints and not to delay the deployment of the third and last questionnaire. During this time, two of the experts ceased to respond, so, by June 14th the decision was made of carrying on with the data collection without them. Their answers were considered in order to produce the second questionnaire, but for obvious reasons, their answers were not present in the second questionnaire and did not impact the last one. Thus, the number of experts participating went from ten to eight. Literature recommends a minimum of ten and a maximum of eighteen, however, this is just a recommendation, as the original Delphi Method developed by the RAND Corporation was carried out with only seven participants (Dalkey & Helmer, 1963).

On June 8th, the answers from the second questionnaire were analysed (read subchapter below) and, as according to literature, especially Okoli & Pawlowski (2004), the

[7] Check Annex 7.1.2. for the complete Google Forms with the Second Delphi Questionnaire.

options with no selection were eliminated (as there was already a consensus on them not being appropriate answers to the posed questions) and the other ones were written down. On the same day, an email was sent to the experts with the link to the third questionnaire, its explanation, and a copy of their answers to the second questionnaire.

The third and last questionnaire[8] consisted of the same four questions and the options were the alternatives selected in the second questionnaire. This time, experts were asked to not only validate their answers, but also rank them. They could rank two answers the same number if they considered them to be equally relevant. This step was crucial to understand the meaning and value that each factor or component has to a given expert and to understand its standing in the general STEAM education and educational robotics landscape.

The questionnaire was sent on the same day and experts were given until June 20th to answer. This marked the end of the Delphi Method data collection process, which had begun on April 15th, after the predetermined third and last questionnaire. After completing their participation in the study, the experts were given a consolidated list of their answers to each of the questionnaires.

3.1.3. Data analysis & interpretation

The data analysis phase was done intermixed with the data collection. This is part of the iterative nature of the Delphi Method.

The results from **the first Delphi questionnaire** were analysed before the deployment of the second one. Given the fact that experts were able to answer freely, it was crucial in the end of this first iteration, to compile the answers, synthesise them, and unify the terminology[9].

What is the 'A' in STEAM?

Concerning this pertinent question, experts, succinctly came through with four main answers. They consider the 'A' to be either Design/Design-Thinking, Visual Arts/Aesthetics, Creativity, or Humanities/Liberal Arts. Some experts felt very sure and

[8] Check Annex 7.1.3. for the complete Google Forms with the Third Delphi Questionnaire.

[9] Check Annex nr. 7.2.1. for the First Delphi Method Questionnaire data collection results (summary).

exclusive about their answer, while others considered that there could be more than one right answer.

EXPERT 1: The first expert believes the 'A' stands for creativity, which is a skill one can learn. Her idea is that the objective of the 'A' in STEAM is to teach students to be creative, as "more than half of the students who start the programme will be working in a profession that does not yet exist". That is what makes STEAM different from STEM, the choice of focusing on creativity and problem-solving. According to her, this can be enhanced by subjects like Design-Thinking, where students need to be creative and look for solutions to certain problems. It is also important that beyond functionality, students understand the importance of the aspect of the product or solution, as it will impact its performance in the market. So, according to this first specialist, the 'A' in STEAM goes beyond the Arts and focus above all in creativity, as it is one of the most important skills in the 21st century.

EXPERT 2: This particular expert believes the 'A' is the leading letter in STEAM and in his work, and his point of view establishes that Design-Thinking and the Arts define the use of technology in a softer and more attractive way.

EXPERT 3: The third expert is unsure of what the 'A' can encompass. He knows it means the Arts and that it definitely brings aspects from creativity and aesthetics to more technical subjects. He is, however, on the fence regarding the Humanities. He stresses how important they are in education and in life in general but does not know if they can be considered part of the 'A' in STEAM. This, once again, alludes to what is already clear in the readings regarding the lack of clarity and even confidence of educators when it comes to implementing STEAM, especially concerning the incorporation of the 'A'.

EXPERT 4: According to the fourth expert, the 'A' visibly stands for the Arts, which he notices that sometimes appears uncapitalised, i.e., STEaM, and considers that this diminishes the importance in comparison to the other areas comprised in the acronym. He goes on to say that the 'A' component encompasses a wide spectrum of activities and skills related to the artistic field, which can be visual arts, expression arts, plastic arts, musical arts, and so on. He considers that by combining the Arts with STEM, there is an expansion of the ways we can approach problems and learning scenarios. Therefore, we empower students to create solutions that are broader in terms of applicability. Still, going beyond the practical application of the 'A', it can bring a dose of personal expression to STEM activities.

EXPERT 5: He considers the ‘A’ to be creativity, as well as empathy, imagination, design, and innovation not only for the implementation of artwork in STEM, but of STEM in Arts as well.

EXPERT 6: She reflects that, traditionally, the ‘A’ stands for the Arts, but she recognises that in her practice, it embodies elements like creativity, design-thinking, culture, Humanities (such as Sociology, Anthropology, Applied Psychology, to name a few) articulated with traditional Science, critical thinking, innovation, and adaptation to the challenges we face today.

EXPERT 7: He considers the ‘A’ to stand for the Arts and that it is an important part of his work in the STEAM realm. He believes it brings a holistic aspect to education, by preparing students for the future and fostering the well-known 21st century skills like, for example, creative problem-solving. Creativity is where he considers the Sciences, and the Arts meet.

EXPERT 8: This expert considers the ‘A’ to stand for the Arts.

EXPERT 9: For the penultimate specialist, the ‘A’ stands for the Arts and the Humanities.

EXPERT 10: The last expert considers the ‘A’ to include, besides the obvious Arts, the essence of design-thinking that is crucial to STEAM projects.

One aspect that stood out was that most participants cited the ‘A’ not as a specific subject or group of subjects (e.g., Fine Arts, Humanities, etc.), but as standing for competencies or behaviours (e.g., creativity, critical thinking, imagination, etc.). This was also present in the literature but refuted by many because how it often leads to the frivolous and diminished inclusion of the ‘A’ in STEM (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015). Even in a semantic way, perhaps it is not correct or entirely right to say that the ‘A’ in STEAM, which we know generated from the addition of the Arts to STEM, stands for creativity or design-thinking. It is factual and accurate to say the addition of this component benefits and fosters these kinds of skills, however, the ‘A’ should not be perceived as the skills themselves.

Another interesting thing to grasp was what experts considered to be the existing gap between **how the ‘A’ in STEAM is being included** and **how it should be included**, because often what ought to be is not necessarily what is.

How the 'A' is included in STEAM

EXPERT 1: This expert mentioned projects, not only curricular (for e.g., a project about AI and language with subjects such as *Lord of the Rings, Percy Jackson,* Shakespeare pieces, and so on) but also external, such as Erasmus+. So, it is clear, even from literature, that STEAM is being implemented in schools mostly through projects whether they created a new subject to implement them or through "regular" disciplines. Another project example given by one the participant was the relationship between a Mondrian[10] painting and the Pythagoras tree[11], or even the relationship between Mathematics and Jan van Eyck's *Virgin and Child with Canon van der Paele*[12]. She also accentuated how hard it often is to insert them in the current curriculum, "These are very nice projects to do but it is sometimes difficult to implement them in the current curricula because they are already overflowing. So, sometimes, we look at doing the projects in the afternoon with the pupils".

As it is clear both in literature but with the overall group of experts, not just the ones who participated in the Delphi Method, but also the ones in the CIT, the biggest problem concerning the curriculum, besides the lack of flexibility, is the fact that it is overflowing with contents. This leaves little room for teachers to implement or try any other kind of experiences and ideas, which jeopardises students' opportunities to interact with real-world problems and make connections between the contents they are learning and reality.

EXPERT 2: This particular participant noted that STEM is completely different from STEAM, and that by adding the 'A' as Arts and design-thinking makes this whole pedagogical model flourish and keep going. He reminisces about the teachers he knows and works with in Finland, by reflecting on their interest in Arts and their willingness to participate in and organise STEAM modules in their school.

EXPERT 3: He reflected on the biggest challenge he witnesses besides the technical development, which is the fear some people have of the "bad side" of technology, i.e., the

[10] Piet Mondrian (1872-1944) – a Dutch modernist painter known for his geometric art.

[11] Pythagoras tree – Plane fractal constructed from squares. Invented by Albert E. Bosman in 1942 but named after the Greek mathematician because it makes use of the Pythagorean theorem.

[12] Jan van Eyck (1390-1441) – a famous Dutch painter and one of the most important figures in the Early Northern Renaissance.

Virgin and Child with Canon van der Paele (1434-1436) – One of van Eyck's most recognised works ad consider a "masterpiece of masterpieces".

impacts on society and the job market. He attributes this to the lack of conversation in and out of school and even between intellectuals and the masses regarding these matters, “In my opinion, there is only a discussion twice a week in newspapers, but not really in schools or between professionals and «normal» people”. He then explains this dichotomy which on one side has “normal people”, who have their reservations towards this mass implementation of innovation and technology everywhere, and professionals, who look forward to it enthusiastically.

This was also seen in the literature, not only regarding the representation of Robotics in media, specifically Science Fiction (Bartneck *et al*., 2020; Gnambs & Appel, 2019; Veruggio *et al*., 2016), but also the gap existent between intellectuals and the masses (Einstein, 2006; Kagan, 2009).

EXPERT 4: The fourth expert, from Portugal, conscious of the limitations of his own experience and knowledge, gathered from his observations of presentations, works, and through contact with other teachers, that the Arts and Humanities are still not being properly included in the planning and/or application of STEAM activities/projects. He assigns this to a variety of reasons like, for example, the lack of teacher training, overall misconceptions regarding the implementation of the STEAM pedagogy (as often seen in literature), or even logistical issues. This eventually prompts the trivial and superficial application of the Arts and Humanities to STEM, where students are required to apply decorations or “give their personal touch” to a certain technology or assignment. This leads to the undermining not only of the Arts and Humanities, but also of students’ potentials.

This particular experts touches on two specific topics that were constant throughout the readings and in the data collection, that is, the need for teacher training, so they can be better allies to STEAM implementation and enhance to the maximum the potential of a pedagogy like this, and the global misconstructions existent regarding STEAM education (Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019).

EXPERT 5: Interestingly enough, this participant pondered over the fact that he considers to be easier to include STEM in Arts, than Arts and Humanities in STEAM, because of this same reason. He considers that implementing the Arts in STEM education can often feel unnatural and does not highlight their proper value and utility. Still, he believes it is crucial to keep on looking for ways to include the Arts in STEM and to make this inclusion more natural and genuine, because, as he sees it, the Arts can be a useful tool for making learning contents visible in the real world for students.

EXPERT 6: This precise expert pointed out that the reason why STEAM is being introduced in schools is the demand of our 21st century economy and society for well-rounded individuals and professionals, which will certainly reflect in the products and activities they carry out. Although she did not provide any clear example of how it is being implemented in Romania, as she does not work in schools, but often with schools, she further reiterated the reasons present in literature for the demand for change in how we teach and learn, so our next generation is better prepared for the future with all the knowledge can have regarding new technologies. This obviously reinforces what is stated in all literature regarding STEAM education and its emergence.

EXPERT 7: What is present in literature regarding the lack of clarity associated with STEAM (Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019) is reiterated by another specialist who agrees that the concept is still relatively new, and it is far from being incorporated into the everyday school life. He refers to some schools in Wachtberg, Germany, who do the incorporation successfully but highlights that the initiative often comes from individual teachers rather than from school boards or higher authorities. He acknowledges that there are some guidelines and frameworks regarding this subject, but that in practice things are often much different and do not translate well from paper to reality.

EXPERT 8: She believes the 'A' component is often times present, but teachers do not consider them to be equally important to the other areas present in STEAM, and that is why she considers that teachers need to receive the proper training to understand this facet of the acronym so they can better implement it.

EXPERT 9: The penultimate expert shares that in her context, in Finland, the 'A' is quite emphasised within STEAM, because it is considered the cornerstone of the acronym. This exact thought should somewhat be evident as it is what differentiates STEM from STEAM, however, because the focus is often times in the more technical areas, it is easy to see the 'A' simply as a tool used to the benefits of others instead of a component of weight by itself.

EXPERT 10: He considers that the fact STEAM is not so technology focused, or it should not, be is what makes it "sell", as another expert mentioned, not only to schools, but to teachers, parents, and students, specifically girls, who have left out of STEM for decades, if not centuries.

For the most part, experts corroborate what is stated in the literature pertaining to these themes. It is clear that in some environments and contexts, the 'A' is being better included,

while in others there is still some effort into figuring out the best way of pursuing it. Because there are no clear guidelines or years of research that prove a certain method works best, teachers and educational institutions are doing their best to recognise around them the efforts, as well as what seems to work or not.

How the 'A' should be included in STEAM

EXPERT 1: Although stating that we are far from the perfect implementation of STEAM with the proper inclusion of the 'A', this expert believes the school she works at in Belgium to be on the right track of applying STEAM with the Arts and Humanities in its curriculum. However, she highlights that it is still not an easy task and that students often need prior knowledge so the implementation can be smoother. She noticed that some projects are not at all easy for first year students (12-13-year-olds), and that after some prior preparation, such as a programming class or workshop, they were able to do things much more successfully. She goes on to say that she believes it is best to not create STEAM as a separate subject, but to include it projects inherent to "regular" classes. She, of course, notes that this would have to take away time from the curricular contents, which is an issue that needs to be solved.

Hence, she believes STEAM should be implemented according to its essence, which is, instead of creating a new subject, combining all the existing ones via collaboration. Nevertheless, because she highlights the potential need of providing students with prior knowledge before initiating a STEAM project/activity due to difficulties in, for example, programming, showcases, perhaps, a lack of adaptability to the level and context of a given grade. Even more, it showcases how it can often revolve much more around the technological aspect, such as with programming, instead of bridging all disciplines of the acronym.

EXPERT 2: He believes Arts play a big role not only in education, but in the outside world as well. Nonetheless, he is of the opinion that we should not overly focus on ways to highlight the 'A' in detriment of the other letters of the acronym, and to do it in a natural and organic way, depending on the project or activity's goals and what the teachers intend.

EXPERT 3: He shares his belief that STEAM should be a crucial part of every school's curriculum, which, of course, is still far from reality. He states that any type of inclusion of STEAM can be helpful for its further implementation and expansion, so the preparation of students for their future is not a matter dragged on through time.

This last thought can help contextualise the overall opinion of the experts that any STEAM implementation initiative is better than none. Any effort in trying to include the 'A' in a proper way is better than not trying. Although this should not function as an excuse for the poor implementation and execution of this recent educational pedagogy, it can serve as an evidence of hope that practice will eventually make perfect.

EXPERT 4: The fourth specialist believes the inclusion of the Arts and Humanities in STEM should be made from the ground up, that is, be inherent in a given project or activity's essence or context. This way, the 'A' in STEAM provides much more than just an aesthetic facet, by contributing to the purpose and direction of what is being created. He gives the example that teachers can plan their STEAM activities, so it allows for discussion of cultural impact, sensibilities, perceptions, and so on. He adds that students' backgrounds and ethnicities should be included as they can foster vital and incredibly rich new perspectives. He finalises by reinforcing the already discussed idea that not every activity will have to bring focus to every area included in the STEAM acronym. Teachers should be able to look at STEAM as a way of transdisciplinary teaching rather than trying to hit all the marks or checkboxes for what is being included or not. For this to happen more naturally, they need to receive the proper training to be able to think outside of the box and acquire the necessary skills to develop more holistic and rewarding learning experiences.

This expert highlights not only how much the Arts, in a Fine Arts sense, can contribute to students' education, but provides tangible ways of also including the Humanities in a personal and relatable way, as it is to bring to the table the youth's own experiences regarding their culture, environment, and community.

EXPERT 5: The fifth expert considers that in an ideal world, the Arts would not only be approached in an integrative way, but also in an interdisciplinary and transdisciplinary form. If such, students would be able to see the Arts and STEAM as two disciplines that work together perfectly. This way, the distinction between including the Arts in STEM or STEM in Arts would cease to exist.

This follow the line of thought present in the readings done, which hopes for the 'A' to be seen as part of the conversation and not just a catalyst for the other areas of knowledge (Bakhshi *et al*., 2008; Bèrubè, 2003; Dumitru, 2019).

EXPERT 6: This expert particularly highlights how the 'A' in STEAM is more naturally integrated in the business world, where adaptation and innovation equal growth and profit. In education, she considers the situation to be different because there is a lot of reluctancy to change the traditional pattern and because there is no proper tangible or

palpable consequence (such as immediate or almost immediate profit). She recommends policy makers to pay closer attention to how things are being done in the business field, and to bring more knowledge and practices from that sector into education. This encompasses teacher training and the creation of contents and contexts where students are exposed to real life problems and have the task to produce creative, innovative, and sustainable ideas to solve them.

EXPERT 7: He deems that the STEAM pedagogy can only succeed if teachers are given the freedom they need to prepare appropriate activities and content for their students. He corroborates the other experts' opinions who also believe this is only possible by providing teacher training and good teaching materials. He stresses how much practical ideas are needed in this area of education. He also emphasises the need for each school to choose what it is best for their context and students, paying close attention to individual strengths and the social environment. That is why he considers plans crafted by people that do not closely work or know the educational sector from the perspective of an educator or a 21st century student does not work or are not effective. He proposes the idea of creating more grassroots projects that has in mind schools' specific framework and necessities, as well as cooperation with extracurricular educational institutions that offer students their services in the morning and/or afternoon.

EXPERT 8: Although the 'A' component is almost always present, teachers do not always notice or consider it. This expert underlines how important, once again, it is to show teachers, via teacher training or some sort of sensibilisation, that the Arts are as equally important as the Sciences, Technology, Engineering, or Mathematics. This could be said for everything in life, because in reality things are not compartmentalised or stripped of any kind of articulation or collaboration. If we look closely, we can find almost always aspects of all sorts of areas of knowledge in our day-to-day lives, which is also true in education. Therefore, it is proving the presence of the Arts and Humanities, but rather understand how to make them excel and communicate with the other areas.

EXPERT 9: Despite the fact that STEAM has been gaining much more momentum than its predecessor STEM, it often is implemented with a focus on the "hard" subjects, that is, the areas comprised in STEM. Therefore, one thing that needs to change, according to the penultimate expert, is the focus shifting from just the technical areas to the articulation between these and the Arts and Humanities, the "soft" side of STEAM. This can include the Arts (visual, Fine Arts), creativity, well-being, and so on.

EXPERT 10: This expert shares how in his school's design projects, in Finland, the Arts and Humanities have the same relevance as Mathematics or Engineering, which leads to most school staff sharing the opinion that those STEAM activities are one of the most important parts of the curriculum.

In general, it is clear that all experts are in a certain alignment regarding how the 'A' should be included in STEAM. The key point to pay attention to is that something goes wrong when going from theory to practice, which is something further discussed in this dissertation, as the experts, specifically the ones who participated in the CIT method (read next subchapter) were asked to reflect on the biggest obstacles to STEAM implementation.

Of course, it was imperative to question the participants on the main research question, not only to know their opinion, but to see if they had any sort of tangible example they had tried or seen before and that they considered to have potential.

What contributes to the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics

EXPERT 1: The first expert thinks STEAM education goes beyond Robotics and that we should not perceive it so narrowly. She stresses it is important to understand how far the concept of Robotics extends, in order to better prepare and implement it in schools and within STEAM. She personally believes it is much more important if students learn to see the bigger picture concerning the world and its issues, rather than learn programming. This thought that one needs to reflect and outline the scope of a concept can be applied to anything. Yet, in terms of this dissertation, it is quite relevant to regard it towards the 'A' in STEAM, as seen in the literature, and, like this expert mentions, what we mean by Robotics. The latter was already discussed in the contextualization of this dissertation (read the introduction chapter). However, it would be pertinent to further investigate this.

EXPERT 2: This expert proposes an interesting inclusion of the 'A' in STEAM articulated with Robotics, by having students reflect on the outlook, that is, for example, questions like: "What is the purpose of a robot?", "How does a robot fit into our world (nature, space, colours, etc.)?", and so on.

EXPERT 3: This particular specialist shares how his school in Germany approaches this subject, which is by prompting their students to reflect and discuss the chances and risks

inherent to the implementation and usage of Robotics in our world, as well as acknowledge and leverage on how important they have become.

In here it is clear that, even if in a subconscious way, these experts, 2 and 3, understand the role of Ethics, and therefore Humanities in general, in reflecting and analysing key issues that affect society and humanity as a whole. This can corroborate the concept that the 'A' in STEAM means much more than just the Fine, Visual Arts, but also encompasses the Humanities.

EXPERT 4: He reiterates what is seen in literature by confirming that in the last few years, Robotics has seen a surge in education (Nunez, 2016), due to both the educational and industrial sector realising how important this area of technology will be in future professions. He continues by stating that robots can be used in tandem with the Arts as a way to achieve new and creative methods of expression. So, they are, in a nutshell, tools. Tools that can allow for a new and ground-breaking level of interactivity never seen before in education. With this being said, he reinforces that the inclusion of Robotics in STEAM should be done with a high focus on the Arts and Humanities, exemplifying that we could consider them as future dance partners or performative artists, which there also examples in writing (Montero & Jormanainen, 2017). Robots could also be perceived as communication and language trainers. He concludes by stating that robots, as any other tool, are meant to facilitate processes. With this in mind, teachers should determine if their artistic and humanistic learning goals can be enhanced or not through the usage of Robotics. If so, it is crucial to experiment, observe, and write down the results, in order to gauge if it has or not a positive impact in the students' learning experience and if it fosters skills development.

This last thought helps to justify this research which aims to bring further knowledge from the perspective of educators and other acting figures in these realms concerning key issues like the inclusion of 'A', what it consists of, how it can be best included, and so on. It helps further the conversation and bring even more awareness to it.

EXPERT 5: This expert enhances the idea that the 'A' in STEAM and Robotics might seem unrelated at first but continues to say that the truth is that both concepts elevate each other to a higher level. This way, Robotics can be a facilitator for the implementation of the STEAM pedagogy in education. He shares the experience he has from his school in Belgium, where they organised an Artbot camp, which is a 3-day initiative for primary school students to foster their contact with both robots and art. The students worked on a theme and programmed robots to perform an art form (e.g., dance, reciting a poem,

painting). Once again, this last example goes along a certain line seen in some scholars' work (Montero & Jormanainen, 2017).

EXPERT 6: She agrees with previous experts who stated Robotics can be the perfect instrument to introduce challenges and instigate problem-solving according to students' level of understanding. The usage of robots or robot technology to address more complex issues form both technical, individual, and societal perspectives and include Ethics as a variable that can help students have a better understanding of the complex role that technology has in our lives and the role they can potentially have as future creators of technology.

EXPERT 7: The seventh expert suggests the interaction between a group of people interest in Arts, or even community artists, and students from the local school. This way, a cultural circle is fostered, as well as a relationship between students and their community. Additionally, students could talk with older people and try to comprehend the effects of being alone and question them on whether they consider a companion robot would be a potential solution. Later, they could go back to the artists and discuss the design of a prospective companion robot and reflect on questions such as: features, how they would move, how they would look like, etc. These types of experiences would help students broaden their mind from both an educational but also personal point of view. In order to be able to accomplish something like this, this expert reinforces the idea that schools need to free themselves from their "close-minded" image and open themselves up for their community.

As previously highlighted, whether it is conscious or not, the essence of Humanities is present in almost all experts' answers, because they want to foster in their students a relationship with the world that goes beyond books and its contents, and into reality and their specific community.

EXPERT 8: This expert says it is difficult to understand what would contribute to the ideal inclusion of the 'A' in STEAM with Robotics, because in some way the 'A' is already included, although it is not always perceived. The 'A' is present when students design a solution, think of a model, the materials they will have to use, the shape, the weight, etc. She reiterates that the 'A' is always there, sometimes, however, disguised by the engineering aspect. She adds that even doing the presentation of the product the 'A' is present in the PowerPoint presentation, i.e., the template, the colours, the fonts, photos, etc.

Specifically, the first point is valid to consider given the recent nature of STEAM education. Not enough years of research and results have gone by to fully understand what

is helping and what is not. Therefore, the trail blazers, that is, the ones who are starting to implement STEAM or include it in their context have their task cut out because it is truly a trial-and-error process.

EXPERT 9: The penultimate experts believes that what can best contribute is: the freedom to design, to be creative, to use recycled materials, and to do teamwork and foster social skills, for example.

EXPERT 10: Two examples came to the tenth expert's mind when responding to this question. He shared a project his school carried out with 6th grade students, whose theme was to come up with the best vacuum cleaner (on how it looks and how it works). The task was simple, they had a table full of trash and they had to make their own design and think on how the Blue-Bot[13] would clean the mess in the whole table. In the end of the project, the pupils had to programme the robot. He considered this to be a really easy and fun task. The second activity was carried out with LEGO Mindstorms EV3 robots. The task was to create a fashion show, where the robots were the models. The crucial aspect of this project was the way the robots looked, so students spent quite a lot of time.

In both examples, it is clear that the 'A' component is included in STEAM and articulated with Robotics in a superficial way. It is not to say this is completely bad or incorrect, but it seems there is a lack of depth or thought of its integration. This further proves the notion that STEAM is definitely being integrated in various places, from Portugal to Finland, however, the 'A' is still somewhat seen as an embellishing factor and not as a contributor like the others.

From the synthesised answers above, a list of factors/opinions/perspectives was produced as answers to each of the four questions[14]. This consolidated list gathered from the experts' answers to the first iteration was the basis for **the second Delphi questionnaire**, which, as previously mentioned, consisted of the same questions, but this time around experts could not answer freely, but instead had to select the options they considered valid to answer each question. Every option available was one of the factors/opinions/perspectives given in the first questionnaire.

[13] Blue-Bot – a simple robot that can operate on its own via Bluetooth and that is controlled by an Android, iOS, Mac, or Windows device.

[14] Check Annex nr. 7.2.1. for the Second Delphi Method Questionnaire data collection results (summary).

What is the 'A' in STEAM?

EXPERT 1:

- Design/Design-Thinking
- Creativity

She validated her previous answer.

EXPERT 2:

- Design/Design-Thinking

He validated his previous answer.

EXPERT 3: Did not respond to this questionnaire.

EXPERT 4:

- Design/Design-Thinking
- Visual Arts/Aesthetics
- Humanities/Liberal Arts

He expanded his answer to also include the concepts of design and design-thinking.

EXPERT 5:

- Design/Design-Thinking
- Creativity

He expanded his answer to also include the concepts of creativity.

EXPERT 6:

- Design/Design-Thinking
- Visual Arts/Aesthetics
- Creativity
- Humanities/Liberal Arts

She validated her previous answer.

EXPERT 7: Did not respond to this questionnaire.

EXPERT 8:

- Visual Arts/Aesthetics

She validated her previous answer.

EXPERT 9:

- Design/Design-Thinking
- Visual Arts/Aesthetics
- Creativity

- Humanities/Liberal Arts

She expanded her answer to also include the concepts of design and design-thinking, and creativity.

EXPERT 10:

- Design/Design-Thinking
- Visual Arts/Aesthetics
- Creativity
- Humanities/Liberal Arts

He expanded his answer to include the concepts of creativity and Humanities/Liberal Arts.

How the 'A' is included in STEAM

EXPERT 1:

- There are growing efforts to implement it in schools' STE(A)M curricula
- Mostly done by individual teachers

EXPERT 2:

- There are growing efforts to implement it in schools' STE(A)M curricula
- In a way that attracts a lot more girls than STEM

EXPERT 3: Did not respond to this questionnaire.

EXPERT 4:

- Still very recent
- There are growing efforts to implement it in schools' STE(A)M curricula
- Mostly done by individual teachers
- Slowly, because people fear the technological aspect

EXPERT 5:

- The inclusion of STEM in the Arts is easier than the Arts in STEM
- In order to prepare students for the challenges of today's world

EXPERT 6:

- In order to prepare students for the challenges of today's world

EXPERT 7: Did not respond to this questionnaire.

EXPERT 8:

- There are growing efforts to implement it in schools' STE(A)M curricula

EXPERT 9:

- Mostly done by individual teachers
- In order to prepare students for the challenges of today's world
- Not just technology based
- In a way that attracts a lot more girls than STEM

EXPERT 10:

- There are growing efforts to implement it in schools' STE(A)M curricula
- Slowly, because people fear the technological aspect
- Not just technology based
- In a way that attracts a lot more girls than STEM

Concerning this past question, most experts reiterated their answers and expanded them to encompass new thoughts and ideas they had not previously considered.

How the 'A' should be included in STEAM

EXPERT 1:

- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- STEAM is often seen as a hard subject because it usually emphasises these "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- Schools and teachers should have the freedom to be able to best implement it at their given context

EXPERT 2:

- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- STEAM is often seen as a hard subject because it usually emphasizes the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- Not as a separate subject, but included in the already existing ones

EXPERT 3: Did not respond to this questionnaire.

EXPERT 4:

- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- STEAM is often seen as a hard subject because it usually emphasizes the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- Schools and teachers should have the freedom to be able to best implement it at their given context
- By providing teacher training and teaching materials
- From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)

EXPERT 5:

- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- It should be part of every school's curriculum
- From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)

EXPERT 6:

- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- STEAM is often seen as a hard subject because it usually emphasizes the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)

EXPERT 7: Did not respond to this questionnaire.

EXPERT 8:

- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way

EXPERT 9:

- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- STEAM is often seen as a hard subject because it usually emphasizes the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- It should be part of every school's curriculum
- Not as a separate subject, but included in the already existing ones

EXPERT 10:

- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- It should be part of every school's curriculum
- By providing teacher training and teaching materials
- Through grassroot projects
- Not as a separate subject, but included in the already existing ones

Pertaining to this question, most experts restated their responses and expanded them to include new thoughts and ideas they had not previously considered. Two options were left behind as no expert selected them as a factor/answer to how the 'A' should be included in STEAM: "As a separate subject from the other ones" and "Students should have prior programming knowledge so it can be better applied". Therefore, a clear consensus was already formed concerning the point that STEAM should not be implemented as an extra class, another subject, but rather have its essence incorporated into the traditional classes. The same can be said for requiring students to have prior knowledge in things such as programming. The level of a STEAM activity and project should be adapted to the students' degree of proficiency and their grade in school.

What contributes to the ideal way of including the 'A' in STEAM (K-12) education with Robotics

EXPERT 1:

- Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

EXPERT 2:

- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
- Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)

EXPERT 3: Did not respond to this questionnaire.

EXPERT 4:

- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
- Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
- The use of robots both in visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)
- Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum
- Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

EXPERT 5:

- The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
- The robots as tools to enhance interactivity
- The use of robots both in visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)

EXPERT 6:

- Use the ‘A’ to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
- The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
- The use of robots both in visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)
- Teachers determining the robots/Robotics’ artistic and humanistic learning goals in order to enhance their usage
- Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum
- Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

EXPERT 7: Did not respond to this questionnaire.

EXPERT 8:

- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities

EXPERT 9:

- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
- Use the ‘A’ to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
- Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum
- Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

EXPERT 10:

- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
- Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
- The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
- Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum

ADDITIONAL INFORMATION:

EXPERT 4: The application of Arts in STEM is valuable as both a single school subject or distributed amongst all of them. There is, however, the fact adapting STEAM methodologies to all subjects has to be a thoroughly thought out process, as to not let the initiative fall in the common trappings associated with the A in STEAM. As such, in certain scenarios, the creation of a single STEAM subject may be more appropriate, as it can be used as a cross-knowledge moment where projects can be developed. The distribution of STEAM throughout each subject is, of course, ideal, but it requires several key steps in curriculum planning and teacher training.

Once again, regarding this question, most experts reinforced their responses and extended them to include new thoughts and ideas they had not previously considered.

After the experts responded to this second iteration, the same procedure was performed: the answers were registered, and the similar/identical ones put aside. The two options concerning the third question that were left blank, which was mentioned above, were set aside, as experts reached the consensus, by none selecting it, that it did not respond to the question.

The next important step and determinant of **the third and last questionnaire**[15] was the ranking of the answers. The questionnaire, once again, included the same four questions, but this time, experts had to rank their answers by the order they thought fit best to respond.

[15] Check Annex nr. 7.2.3. for the Third, and last, Delphi Method Questionnaire data collection results (summary).

After this last iteration, the data collection process was considered completed and the answers were, yet again, recorded and analysed, comparing them with the previous rounds and interpreted in order to reach a certain level of consensus regarding the questions posed.

The main objective of this last questionnaire was to understand the level of importance experts gave to their multiple answers and figure out if they could rank them by importance. As previously stated, they were allowed to select more than one option as, for example, a number one priority, which would be interesting to analyse contrasting it with the other data collected (read chapter below) and the information found in literature. Instead of separating by question, this following section, which analyses and interprets the experts' answers to the third questionnaire, will be separated by expert, so it is easier to gauge the experts ranking of each factor/opinion/perspective. An option ranked at number 1 means that it is the most relevant and important to help answer the given question.

Table 2 – Ranking done by EXPERT 1 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
2	Creativity
3	Visual Arts/Aesthetics
4	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	As something still very recent
2	There are growing efforts to implement STE(A)M in schools' curricula
3	Mostly done by individuals
4	In order to prepare students for the challenges of today's world and the future that awaits them
5	The theory vs. practice is still, generally, very different
6	Slowly, because some people fear the technological aspect
7	Slowly, because some people see the value in it and others do not
8	In a way that attracts more girls into STEM
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	Schools and teachers should have the freedom to be able to best implement it at their given context
2	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills

	part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
3	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
4	It should be a part of every school's curriculum
5	By providing teacher training and teaching material
6	Not as a separate subject, but included in the already existing ones
7	Not as a separate subject, but included in the already existing ones
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
2	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
3	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum

Table 3 – Ranking done by EXPERT 2 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
2	Visual Arts/Aesthetics
	Creativity
3	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	There are growing efforts to implement STE(A)M in schools' curricula
	In order to prepare students for the challenges of today's world and the future that awaits them
	In a way that attracts more girls into STEM
2	Mostly done by individuals
3	As something still very recent

4	The theory vs. practice is still, generally, very different
	In a reductive way (as a way to embellish/does not contribute with something of value)
	Including STEM in Arts is easier than including the Arts in STEM
5	Slowly, because some people fear the technological aspect
	Slowly, because some people see the value in it and others do not
6	Not by just including technology into the regular school's curriculum
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
	It should be a part of every school's curriculum
	Not as a separate subject, but included in the already existing ones
2	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	Through school activities/projects
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
3	Through grassroot projects
4	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
	The use of robots in both visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)

	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum
	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
2	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
3	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The robots as tools to enhance interactivity
4	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage

EXPERT 3: Did not respond to this questionnaire.

Table 4 – Ranking done by EXPERT 4 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Visual Arts/Aesthetics
	Humanities/Liberal Arts
2	Design/Design-Thinking
	Creativity
How is the inclusion of the Arts and Humanities in STEAM done?	
1	Mostly done by individuals
	There are growing efforts to implement STE(A)M in schools' curricula
	Slowly, because some people see the value in it and others do not
	In order to prepare students for the challenges of today's world and the future that awaits them
2	The theory vs. practice is still, generally, very different

	In a reductive way (as a way to embellish/does not contribute with something of value)
	Not by just including technology into the regular school's curriculum
3	As something still very recent
4	Including STEM in Arts is easier than including the Arts in STEM
	Slowly, because some people fear the technological aspect
	In a way that attracts more girls into STEM
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
2	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
	Not as a separate subject, but included in the already existing ones
3	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
	It should be a part of every school's curriculum
	Through grassroot projects
	Through school activities/projects
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our

	society and their role in the future as potential technology creators
2	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage
	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum
3	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)
4	The robots as tools to enhance interactivity
5	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system

Table 5 – Ranking done by EXPERT 5 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
	Creativity
2	Visual Arts/Aesthetics
	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	In order to prepare students for the challenges of today's world and the future that awaits them
2	Not by just including technology into the regular school's curriculum
	In a way that attracts more girls into STEM
3	As something still very recent
	The theory vs. practice is still, generally, very different
	There are growing efforts to implement STE(A)M in schools' curricula
4	Including STEM in Arts is easier than including the Arts in STEM
5	Slowly, because some people fear the technological aspect

6	Mostly done by individuals
	Slowly, because some people see the value in it and others do not
7	In a reductive way (as a way to embellish/does not contribute with something of value)
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	Through school activities/projects
	Not as a separate subject, but included in the already existing ones
2	It should be a part of every school's curriculum
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	Through grassroot projects
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
3	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
	The robots as tools to enhance interactivity
	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage
	Robots/Robotics as a way to address more complex issues from technical, societal, and

	individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
2	The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)
	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum

Table 6 – Ranking done by EXPERT 6 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
	Visual Arts/Aesthetics
	Creativity
	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	Mostly done by individuals
	In order to prepare students for the challenges of today's world and the future that awaits them
2	As something still very recent
3	The theory vs. practice is still, generally, very different
	Including STEM in Arts is easier than including the Arts in STEM
4	Slowly, because some people see the value in it and others do not
	Not by just including technology into the regular school's curriculum
5	Slowly, because some people fear the technological aspect
6	In a way that attracts more girls into STEM
7	There are growing efforts to implement STE(A)M in schools' curricula
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics

	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
	It should be a part of every school's curriculum
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	Through grassroot projects
	Through school activities/projects
	Not as a separate subject, but included in the already existing ones
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
	The robots as tools to enhance interactivity
	The use of robots in both visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)
	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage
	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum

	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

EXPERT 7: Did not respond to this questionnaire.

Table 7 – Ranking done by EXPERT 8 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
	Visual Arts/Aesthetics
	Creativity
	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	In a way that attracts more girls into STEM
2	As something still very recent
	The theory vs. practice is still, generally, very different
	There are growing efforts to implement STE(A)M in schools' curricula
	Slowly, because some people fear the technological aspect
	Slowly, because some people see the value in it and others do not
	In order to prepare students for the challenges of today's world and the future that awaits them
	Not by just including technology into the regular school's curriculum
3	Mostly done by individuals
	In a reductive way (as a way to embellish/does not contribute with something of value)
	Including STEM in Arts is easier than including the Arts in STEM
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills

	part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
	It should be a part of every school's curriculum
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	Through grassroot projects
	Through school activities/projects
	Not as a separate subject, but included in the already existing ones
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
2	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
2	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
3	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
	The robots as tools to enhance interactivity
	The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)
	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage
	Create a better relationship between the students and the community they live in by

	interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum

Table 8 – Ranking done by EXPERT 9 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?	
Ranking	**Option**
1	Design/Design-Thinking
	Visual Arts/Aesthetics
	Humanities/Liberal Arts
2	Creativity
How is the inclusion of the Arts and Humanities in STEAM done?	
1	In order to prepare students for the challenges of today's world and the future that awaits them
	Not by just including technology into the regular school's curriculum
2	Mostly done by individuals
	There are growing efforts to implement STE(A)M in schools' curricula
	Slowly, because some people see the value in it and others do not
	In a way that attracts more girls into STEM
3	As something still very recent
4	Slowly, because some people fear the technological aspect
5	The theory vs. practice is still, generally, very different
	Including STEAM in Arts is easier than including the Arts in STEM
6	In a reductive way (as a way to embellish/does not contribute with something of value)
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)

	It should be a part of every school's curriculum
	Schools and teachers should have the freedom to be able to best implement it at their given context
	By providing teacher training and teaching material
	Not as a separate subject, but included in the already existing ones
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
1	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
2	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
	The robots as tools to enhance interactivity
3	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum
4	The use of robots in both visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)
5	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage

Table 9 – Ranking done by EXPERT 10 in the Third, and last, Delphi Questionnaire

What is the 'A' in STEAM?

Ranking	Option
1	Design/Design-Thinking
	Creativity
2	Visual Arts/Aesthetics
	Humanities/Liberal Arts
How is the inclusion of the Arts and Humanities in STEAM done?	
1	There are growing efforts to implement STE(A)M in schools' curricula
	In order to prepare students for the challenges of today's world and the future that awaits them
2	Including STEAM in Arts is easier than including the Arts in STEM
	In a way that attracts more girls into STEM
3	As something still very recent
4	Not by just including technology into the regular school's curriculum
5	The theory vs. practice is still, generally, very different
	Mostly done by individuals
	Slowly, because some people fear the technological aspect
6	In a reductive way (as a way to embellish/does not contribute with something of value)
	Slowly, because some people see the value in it and others do not
How should the inclusion of the Arts and Humanities in STEAM be done?	
1	The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
	It should be a part of every school's curriculum
	By providing teacher training and teaching material
	Through grassroot projects
	Through school activities/projects
	Not as a separate subject, but included in the already existing ones
2	The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
	Schools and teachers should have the freedom to be able to best implement it at their given context
	From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)

3	STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
1	The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
	Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum
2	Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)
2	The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)
	Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage
	Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
3	Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
	The robots as tools to enhance interactivity

It was interesting to see the ranking done by the experts as it pertained to the last iteration and their final thoughts on the four questions. Something worth expanding in the future is the repetition of the ranking, but not allow more than one option to have the same number, and the justification of the choice. Although experts would have to ponder and spend a lot more time responding to the questionnaire, it would be beneficial to understand, when given no other option, what really are the most important factors.

The table below represents the rough consensus reached by the eight remaining Delphi experts to these four existential questions that concern STEAM education. Underlined is the option with most "votes", which, logically, represents the possibility that should best answer the given question.

Table 10 – Consensus reached by the Delphi experts

What is the 'A' in STEAM?	
Option	**Number of experts who placed it in 1st place**
Design/Design-Thinking	7
Visual Arts/Aesthetics	4
Creativity	4
Humanities/Liberal Arts	4
How is the inclusion of the Arts and Humanities in STEAM done?	
As something still very recent	1
The theory vs. practice is still, generally, very different	0
Mostly done by individuals	2
In a reductive way (as a way to embellish/does not contribute with something of value)	0
There are growing efforts to implement STE(A)M in schools' curricula	3
Including STEM in Arts is easier than including the Arts in STEM	0
Slowly, because some people fear the technological aspect	0
Slowly, because some people see the value in it and others do not	1
In order to prepare students for the challenges of today's world and the future that awaits them	6
Not by just including technology into the regular school's curriculum	1
In a way that attracts more girls into STEM	2
How should the inclusion of the Arts and Humanities in STEAM be done?	
The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics	4
The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	5
STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to	4

highlight the "soft" skills (creativity, critical thinking, well-being, etc.)	
It should be a part of every school's curriculum	5
Schools and teachers should have the freedom to be able to best implement it at their given context	5
By providing teacher training and teaching material	5
Through grassroot projects	3
Through school activities/projects	4
Not as a separate subject, but included in the already existing ones	6
From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	4
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities	6
Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)	3
The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system	3
The robots as tools to enhance interactivity	2
The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)	2
Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage	2
Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum	3
Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our	5

Hence, according to the data collected, we can say a rough consensus was achieved in every question. However, there are some doubts about its true reign as the number one answer, as here was not enough time to administer more questionnaires and eliminate more factors. However, because this is not the only method employed in this research, the data can be utilised with a grain of salt by also making use of the data collected in previous rounds of the Delphi Method, specifically the first one, where experts were allowed to provide more detail to their answers.

The rough consensus determined that:

- The 'A' in STEAM stands for the concepts of design and design-thinking.
- The inclusion of the Arts and Humanities in STEAM is done in order to prepare students for the challenges of today's world and the future that awaits them.
- The inclusion of the Arts and Humanities in STEAM should be done not as a separate subject but included in the already existing ones.
- And, what most contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics is the freedom for schools, teachers, and students to implement STEAM the way it best suits their necessities.

3.2. Empirical Study II

3.2.1. Critical Incident Technique

The Critical Incident Technique was created in the 1940s by John Flanagan, an American researcher in occupational psychology (Flanagan, 1954). He developed it as a way to "gather and analyse objective, reliable information about specific activities" (Hughes, 2008, p. 50). Since then, the CIT has been used in a plethora of areas and fields (Gremler, 2004; Hughes, 2008).

As the name itself implies, the CIT is "the study of *critical incidents* – or significant instances of a specific activity – as experienced or observed by the research participants" (Hughes, 2008, p. 50). Through interviews, the typical method of data collection, the Critical

Incident Technique allows the gathering of rich and unique data regarding the interviewees' experience and knowledge in their own words. The respondents' are questioned on their perspectives and opinions, as they are simply asked to recall specific events or situations where they took part in (Gremler, 2004). Due to this, the interviewees' answers enable the formation of patterns, from which researchers are able to produce concepts and theories (Olsen & Thomasson, 1992 cited in Gremler, 2004, p. 67; Hughes, 2008).

As designed by Flanagan, the method itself is very flexible and can be modified or adapted in order to meet the study's needs and requirements (Flanagan, 1954, p. 335). Nonetheless, Flanagan, (1954) provided a clear and defined research process that encompasses five steps:

1. Establishment of the general aims of the study;
2. Establishment of the data collection plans and specifications;
3. Collection of the data (interviews);
4. Analysis of the data collected;
5. And, the interpretation and dissemination of the data.

According to Hughes (2008, pp. 53-62), the first phase, the establishment of the general aims of the study, is essential to define what activity is going to be studied and what is the primal objective of the study. It is followed by the establishment of the plans and specifications for the data collection, the second phase of the process, where a "plan of attack" is designed in order to carry out the actual data collection via interviews. The researcher has to map out four crucial things: (1) the situation (the location, conditions, and the participants in the study); (2) the relevance (where the researcher specifies the critical incidents and what type of critical behaviours are valuable to the study); (3) the extent (what is the criteria to filter the critical incidents that are deemed relevant); and (4) the observers (that is, if more than one researcher is helping in conducting the study, they all should be very familiar with what is being investigated). The third phase is the data collection phase itself. Individual interviews are the most common and preferred way of collecting the necessary data. It is crucial to inform the interviewees about the purpose of the study and why they were selected, as well as stress the preservation of their anonymity. It is also key to carefully craft the interview script in order to minimise bias. Regarding the number of participants, there are no specific rules about the sample size. It is rather about what makes the most sense for the study. The penultimate phase, the analysis of the information collected, aims at categorising critical incidents and identifying critical behaviours. These are organised in a series of well-crafted categories and sub-categories that decrease in

generality and increase in specificity. The last phase is the interpretation and dissemination of findings in accordance with the objectives of the study. There is no particular way of showcasing the results, although they usually include a list of the critical behaviours that explain the nature of the investigated activity.

Despite the many proven advantages, the CIT has been criticised for having reliability and validity issues, as it can be fairly easy for interviewees to have bias (Michel, 2001 cited in Gremler, 2004, p. 67). Nevertheless, since its emergence in the 1940s with (Flanagan, 1954), it has been proven to be a solid research method (Gremler, 2004; Hughes, 2008).

The CIT was selected for this research because it enables for a more thorough and personal perspective of key-people in its main areas. For its previously mentioned flexibility and adaptability (Flanagan, 1954, p. 335), it fitted perfectly with the investigation's scope, calendar, and planning. It was also beneficial given the rather modest literature available on the articulation of the subjects, which contributed to the increase in knowledge (Gremler, 2004) surrounding especially the two auxiliary questions - *How are European schools implementing STEAM (with Robotics)?* and *What do experts and practitioners say on the current inclusion of the 'A' in STEAM and on how it should be included?*. It is, therefore, regarded as being best suited for this type of study, exploratory, and where one tries to make sense of specific activities and create a basis for further researches and practices (Hughes, 2008).

3.2.2. Data collection

Following the guidelines found in literature (Flanagan, 1954), the **first step** was to **establish the general aims of the research**, which were determined to be:

- Understanding how STEAM education is being implemented in Europe with or without Robotics;
- Understanding how the inclusion of the Arts and Humanities in STEAM is being done *versus* how the experts think it should be done;
- And, understanding what the ideal way of would be including the 'A' in STEAM (K-12) education regarding Robotics.

The way to fulfill these aims was by conducting one-on-one interviews with key-people who work or have worked in the education, STEAM education, Robotics, and/or educational robotics, in order to:

- Gather information;
- Understand the reality of these matters (the three main subjects of the research and their articulation and relationship);
- Widen the knowledge provided by the literature;
- Adopt a critical perspective and minimize my own bias;
- And, finally, create new knowledge based on what experts have to say from their mastery and experience.

The **second step**, where one establishes the **plans and guidelines for the data collection itself**, pertains to determining critical incidents and documenting critical behaviours. Flanagan (1954) advised to mindfully register this information as a way to assure the researcher's uniformity and objectivity. According to Hughes (2008, pp. 53-55), the four main things to consider are:

1. **Situation** – the location, conditions, participants of the study, and the reiteration of the activity;
2. **Relevance** – definition of the types of critical incidents and critical behaviours that are pertinent for the investigation and, therefore, worthy of being studied;
3. **Extent** – criteria for collecting critical incidents based on their significance;
4. **Observers** – the main researcher has to ensure that all other researchers involved are familiar with the study and with the plan for the data collection[16].

Table 11 – Plans and specifications for the present research (based on Hughes (2008))

Aims	Understand how STEAM education is being implemented in Europe with or without Robotics. Understand how the inclusion of the Arts and Humanities in STEAM is being done *versus* how the experts think it should be done. Understand what the ideal way of would be including the 'A' in STEAM (K-12) education regarding Robotics.
Activities	Gather information; Understand the reality of these matters (Arts & Humanities, (STEAM) education, and Robotics and their articulation and relationship); Adopt a critical perspective and minimise my own bias; And, finally, create new knowledge based on what the experts have to say from their mastery and experience.

[16] Not applicable to the present research, as it was only conducted by a sole researcher.

Situation	**Who?** Six European experts on (STEAM) education and/or (educational) Robotics. **Where?** Zoom meetings[17] **What?** Understand their standing, based on their expertise and experience, on how STEAM education is being implemented in Europe (with or without Robotics); and on how the 'A' is being included in STEAM *versus* how it should be included.
Critical incidents	Experts' experience and observation of any/all situations and actions that involve STEAM education in Europe, educational robotics, and the Arts & Humanities in education.
Critical behaviours	Any/all situations and actions that involve STEAM education in Europe, educational robotics, and the Arts & Humanities in education.
Extent	Given the exploratory essence of this study, the extent of the collection is broad in order to not overlook any important information.
Observers	Sole researcher. Ensure the conduction of the rigorous data collection plan. Due to the scope of the dissertation, familiarity with the subjects was achieved via readings and with the data collection process itself.

In order to move forward to the next phase, the collection itself, a thorough and conscientious research was conducted in order to find the *perfect* experts to be interviewed. This research was mostly based on the readings conducted for the state-of-the-art stage of the dissertation process, where a list of 93 potential experts was conceived. However, with the time constraints of the dissertation and with the fact that the data gathering depends on the experts' immediate availability for the study, some criteria needed to be defined and some decisions needed to be made. Since there are no scrupulous rules on how the experts should be selected, a few liberties were taken, as it was only important to stress that they were experts in the subjects relevant to the study. As the world still battles the COVID-19 pandemic, and the background of the experts needed, education, is complex and time consuming, the experts who were of easier contact and who responded more rapidly were the ones chosen to participate. Still, so as to achieve a careful and rigorous collection of

[17] **Zoom** → Video communication software (https://zoom.us/pt-pt/meetings.html).

data, the experts thought of were all experts and/or practitioners in the fields of the Arts & Humanities, (STEAM) education, and/or Robotics. This way, even with a looser way of choosing the final participants, the quality and relevance of the information shared was secured.

Initially, five experts were contacted from five different countries (Portugal, Italy, Spain, Belgium, and Germany), ranging from educators to engineers. The contact was done via email in the first weeks of April 2021. One extra expert was suggested by one of the already invited experts and the contact was established a couple of weeks later.

Table 12 – Critical Incident Technique Experts Profile

Expert	Profile
A	• From Germany • Consultant at a Robotics and related technologies company
B	• From Italy • Vice-president of an educational robotics institution
C	• From Belgium • Principal at a Belgian semi-private school (K-12)
D	• From Spain • STEAM teacher at a Spanish private school (K-12) & teacher trainer
E	• From Belgium • Teacher at a Belgian semi-private school (K-12)
F	• From Portugal • STEAM coordinator at a Portuguese private school (K-12)

Simultaneously to the contact of the experts, the script for the semi-structured interviews[18] was written. The script consists of ten fundamental questions that helped assess critical incidents and behaviours relevant to the study, hence aiding in the answering of the research questions:

1. How does your work relate with STEAM or Robotics and its implementation in the European context?
2. What do you consider to be the 'A' in STEAM?
3. What do you believe is the role of Robotics not only now but in the future? Do you have a more positive, negative, or neutral perspective?
4. Do you think that STEAM, in a school curriculum, should be an extra class, or do you think it should be incorporated into the traditional ones?

[18] Check annex nr. 7.3 for the script of the semi-structured CIT interviews.

5. What do you consider to be the value and the contribution of the Arts and Humanities in education?
6. Do you believe that the current educational system in your country is obsolete?
7. Do you believe the 'A' in STEAM should have the same weight as the other areas?
8. What do you think is the gap between how the Arts and Humanities are **being** included in STEAM and how they **should be** included?
9. What do you think is the biggest obstacle to STEAM or educational robotics implementation?
10. Based on your experience and knowledge, what do you consider to be the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?

So as to take the most advantage from these interactions with the specialists, the ten questions were posed in a specific way, but allowed the expert to elaborate as much as he considered necessary or relevant. This way, the data gathered would go beyond the critical incidents or behaviours and provide additional information relevant to this research.

The interviews were scheduled via email as well and conducted at a day and hour suitable for each participant. They were conducted via Zoom, where the scope and framework of the research was explained, and the anonymity of participants' responses reiterated. The six interviews were carried out between April 16th and May 11th, 2021. The recordings range from 25 minutes to approximately 1 hour. After each recorded interview, a transcript was produced of the most relevant moments of the meeting, which was sent back to the interviewee for approval and knowledge. This way, participants were able to add or take from their testimony, as well as validate their answers, consequently diminishing the potential bias and reaffirming the rigour of the data collected.

Table 13 – Data collection synopsis & experts' profile (based on Hughes (2008))

Participants	Six European experts on (STEAM) education and/or (educational) Robotics. Different backgrounds: Philosophy, Communications, STEAM, Robotics, Computer Science, Education, and Engineering. Five different countries: Portugal, Italy, Spain, Belgium, and Germany.
Data collection activities	Semi-structured interviews via Zoom.
Interviews	Script with ten fundamental questions.

3.2.3. Data analysis & interpretation

Subsequent to the data collection came the data analysis phase. As previously mentioned, after each interview, a transcript was produced based on the recordings. When all six interviews were completed, a synthesis of the overall answers to the ten basic questions was created in order to understand the similarities and differences between each expert's experience and perspective on the matters in question[19]. Simultaneously, the examination of critical incidents and the identification and classification of critical behaviours was completed, according to the literature (Flanagan, 1954; Gremler, 2004; Hughes, 2008).

With regard to the general information collected, that is, that does not only or exclusively concern the critical incidents and behaviours, many interesting experiences and perspectives were amassed. As mentioned in the previous subchapter, six European experts were interviewed, and they all come from different backgrounds and play different roles in the field of STEAM education and/or educational robotics. Their **backgrounds** are in the areas of Computer Science, History, Education, Engineering, Philosophy, and Communications, and their **roles** consists of teacher (STEAM or "regular"), consultant, STEAM coordinator, vice-president, and principal. The diversity of their backgrounds and nationalities, and the range of their roles in the field of education helps to provide equally varied responses, experiences, and perspectives, which contributes to the richness of the data.

As can be seen in the literature regarding STEAM education, given its relatively recent nature, there is still a lot of confusion about its meaning, scope, and practices (Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019). One of the key questions concerning STEAM revolves around **the meaning of the 'A'**. The 'A', of course, stands for the Arts, however, the misunderstanding lies in what one means by Arts, as previously seen with the Delphi Method experts. So, it seemed imperative to question also question the CIT experts on their opinion concerning what the 'A' stands for. Four major perspectives on what the 'A' is surfaced. The two most agreed upon were that the 'A' stands for creativity and for

[19] Check Annex nr. 7.4. for the CIT data synthesis overview.

the Arts and Humanities, i.e., Arts in a broader sense. Close behind appeared Design-Thinking and Arts in a more specific sense (Fine Arts).

'A' as creativity

Creativity already receives a lot of focus in literature as being one of primal dividends of integrating the Arts in STEM (Christensen & Knezek, 2015; Dumitru, 2019; Fattal, 2019; Ghanbari, 2014; Herro & Quigley, 2017; Lewis, 2015; Liao, 2019; Madden *et al*., 2013; Marmon, 2015, 2019; Montero & Jormanainen, 2017; Perignat & Katz-Buonincontro, 2019; Spector, 2015; Stroud *et al*., 2019; Stroud & Baines, 2019; Sullivan *et al*., 2017). The experts (C and D) who spoke of the 'A' as concerning creativity as well did not extend themselves too much on their reasoning behind it. They mostly rallied behind the idea of how creativity is crucial and how much of it is lost as students go through school experience the traditional curricula that has been set for many years. Besides defending the position that creativity is key to our lives, not only as students and professionals, but also as human beings, the experts stressed the notion that creativity is not something that one is born with, but rather something that can be taught/learned and stimulated.

Expert F, although agreeing that STEAM encourages creativity in students and professors, believes that it does not make it the 'A' in STEAM, stating that it is an 'A' for a reason and not a 'C'. He defends that creativity, just as critical thinking, fine motor skills, among others, are competencies one acquires by being exposed to the integration of the Arts and Humanities in STEM.

'A' as Arts & Humanities

Most of the experts agree that the 'A' in STEAM pertains, even if slightly, to the Arts and Humanities, i.e., the Arts in a broader sense. Only one of the experts, expert F, takes the definite position that this entirely what the 'A' stands for. The other five were more inclined to defend that the 'A' is a combination of all the options mentioned above. This particular expert believes that we should perceive the 'A' of Arts as something vaster than the Fine Arts, and definitely not as creativity, as previously mentioned. Thus, the 'A' should be understood in a more humanistic sense, not only encompassing painting, drawing, design, etc., but also History, culture, literature, and so on. This way one guarantees that the inclusion of the 'A' in STEM goes beyond embellishment and aesthetics into something more conceptual and part of the essence of a problem or activity.

The other five experts mentioned competencies and qualities one can garner and be stimulated by in a Liberal Arts education. Competencies such as: reflection, critical thinking, self-awareness, collaboration, creativity, beauty, etiquette, Ethics, culture, to name the most cited ones.

'A' as Design-Thinking

'A' as Design-Thinking was especially stressed by one expert, expert C, as defining the 'A' in STEAM, as he considered this method, which is often a subject in modernised school curricula, to be able to teach creativity, "[…] we have the subject Design-Thinking, a subject in which creativity can be learned". This goes along with this expert's opinion that creativity is not necessarily something like talent, that one can be born with, but more like a skill one can train, "Often, creativity is approached as an aptitude that you have or don't have. For me, it's something you can train. It's a competence and you can train it". He also defends that it is through Design-Thinking that one can make the best and easiest communication between all areas that compose STEAM.

'A' as Fine Arts

The 'A' as Fine Arts is overall seen by the entire group as the basis for what the 'A' in STEAM stands for. It is sort of as the default level where the inclusion of the Arts in STEM begins. Everybody considered the aesthetic part crucial, as it is important to understand the value of beauty and design, and their relationship with the public (e.g., if it is a product, it is important that it is aesthetically appealing to the target audience). However, many supported the idea that one has to be careful with this notion as it can very quickly become reductive and lowered to embellishment without any consideration or strategic thought behind it. They all agreed that it is important to incorporate the 'A', as long as it makes sense, from the very beginning, whether it is a project or activity, or even a class. The Arts part should be included in the essence and context of what is meant to be taught and learned. This way it is conveyed to the students that the Arts have meaning, value, and a purpose that surpasses the visible and physical facet only.

After understanding where every expert had to say regarding the 'A' in STEAM, it was important understand their personal and professional opinion on **the role of Robotics now and in the future**, since this is the chosen technology for the present dissertation. There were answers all across the spectrum, from positive to negative, and even neutral.

Positive perspective

All six experts agree that Robotics is useful and important and will continue to be so for the foreseeable future. One, expert F, even considers Robotics as having a protagonist role in today's world, which goes along with what Veruggio & Operto (2008) dubbed the 21st century to be: 'The Age of Robots'. This stems from the presence of Automation in all sectors of society "from the industrial sectors to ones that maybe were not as much explored before".

Neutral perspective

One particular expert, expert B, defended that it will all depend on the next generation of roboticists. She highlighted the general worry regarding the fact that in the United States, more than 80% of Robotics is funded by DARPA[20], which raises the question of killer-robots and soldier-robots as part of nations' military. She followed by stating that there are already running efforts to prevent this type of usage, "[…] we took part in all the campaigns to stop killing-robots. In the UN there was a motion and an action to stop armed drones in civilian actions and this is very important because as you know, military funding has a big part of the gross product of every nation". She also emphasised how this matter will also depend on how engineering departments view their programmes. She finds crucial the addition of courses such as design, Roboethics, History of Robotics, History of machines, sociology of machines, human-robot interaction, and so on, to balance the crude and technical components.

Negative perspective

The negative perspective mostly resides in the fear that the future plays out like the stories written in Science Fiction. One particular expert, expert D, highlighted this perspective remembering that nowadays mistakes continue to occur and that we might not be ready to keep up with the rapid evolution of complex technology. He agrees that it is for sure helpful and has its positive sides, but the negative ones are currently being overlooked, especially the ethical side of it.

[20] Defense Advanced Research Projects Agency (DARPA), which for the past years "has held to a singular and enduring mission: to make pivotal investments in breakthrough technologies for national security" (DARPA, n.d.).

Because we are dealing with STEAM education, a new form of pedagogy that still lacks clarity on how it should be implemented, it seemed appropriate and necessary to ask the experts if they were of the opinion that **STEAM should be implemented in schools as an extra class or have its essence incorporated into the "regular" classes**. They all share the same opinion that it is a difficult question to tackle because there is still no clear answer. As of right now, most agreed to continue with the extra class solution, however countered their answers with justifications and additional information, and one expert completely opposed to this idea.

STEAM as an extra class

Because school curricula are already so full and time is short, having a fixed spot for STEAM increases the changes of it being implemented. Plus, a lot more projects and activities could be deployed in order to promote this holistic and transdisciplinary educational approach. This allows for the establishment of a foundation for STEAM to be more naturally included into schools' curricula. Given that it is still quite a recent concept and there are not many guidelines about its implementation, having STEAM as an extra class permits for a more careful and thoughtful inclusion.

STEAM as part of the essence of "regular" classes

Expert F vehemently defended that in order to do its theoretical framework justice it should be part of the traditional classes and not restricted to one of its own. This stems from the idea that STEAM is supposed to be the convergence of all areas of knowledge and not the union of these same areas as something different and dislocated. STEAM should be seen as part of the essence of each class, by stimulating the transfer of knowledge and the communication between all areas of expertise. However, the expert compromised, considering the current educational landscape, stating that it can stay as an extra class until there is a better and easier way to integrate it into the regular curriculum. He proposed that this extra classed should not be viewed as another content discipline, but rather as a block of time in students' schedules where they can develop STEAM activities and projects prompted from the collaboration and cooperation of the traditional classes' teachers.

In order for STEAM to become part of every class's essence, it is important that educators understand what the 'A' can bring to the equation so they can better their approach

its inclusion, and therefore, implementing STEAM more efficiently. Thus, they were questioned on what they considered to be **the value and contribution of the Arts and Humanities**. They all agreed that the Arts and Humanities have worth by themselves, and they can highly contribute towards other areas of understanding, specifically the ones in STEM. They also agreed that the Arts and Humanities contribute to cultivate responsibility, responsibility to dream, to find solutions, and to understand how human bias can be minimised. Most believe they promote self-steering, self-regulation, self-reflection, self-knowledge, and critical thinking. Therefore, they help to encourage imagination and passion in students, which can reinforce the talent that is already inherent to every one of them. Expert C believes that the greatest value of both the Arts and Humanities is that they foster creativity and instil design-thinking. Another one, expert F, particularly highlights how the Arts and Humanities allow us to understand our present moment by looking into the past, which grants us the understand of ourselves and of why things are the way they are. In a nutshell, they carry our culture and values.

As the central theme of this dissertation is education, it was crucial to understand the realities of each experts' country and question them on the **current status of their educational system**, specifically public schools. Three main answers emerged: obsolete, mixed, and updated.

Obsolete educational system

Only one of the experts, expert D from Spain, considered its country's educational system to be completely obsolete. He cited the lack of flexibility as the biggest issue, concerning not only the curriculum, but also the teachers and students.

Mixed educational system

Most experts gave a mixed answer. They are of the opinion that although their country's school system is not completely obsolete, it is neither updated or able to keep up with what students should be learning to strive in today and tomorrow's society. They consider their school system to be complex and in need of work, but not totally faulty or outdated. They also deem that the necessary changes are being slowly implemented, however, due to lack of funding or due to historical factors, the modernisation is rather gradual, nonetheless still happening.

Updated educational system

Expert A, who is from Germany, considered his country's school system to be up to date and starting to give students the necessary education for their future. Still, he pinpoints some things that still need to change, such as the curriculum's flexibility and increased teacher training.

As observed in the literature review, there are some scholars and some forms of STEAM implementation that occur in a way that undervalues the 'A'. The Arts are either treated as a means of making STEM education more attractive and easier, or simply as a way to embellish something, becoming part of the process only at the very end and without much consideration (Bakhshi *et al*., 2008; Bevins, 2011; Bush & Cook, 2019; Conradty & Bogner, 2018; Henriksen *et al*., 2019; Land, 2013; Liao, 2019; Liliawati *et al*., 2017; Marmon, 2019; McKeown, 2019; Spector, 2015). Hence, it looked to be significant to question the participants on their opinion regarding **the weight of the 'A' in STEAM**. They all agreed on the 'A' having the same value and importance as the other areas present in STEAM. The reasons given to fundament this opinion are the following:

- Because STEAM and, especially the 'A', fosters creativity and creativity is key. The same goes for Design-Thinking.
- By including the Arts from the very beginning and giving them the same weight, we incorporate them in the context and essence of the contents taught, which makes them even richer and useful to the students.
- The 'A' makes the resolution of real-world problems more effective, and problem-solving skills are crucial.
- Yes, the 'A' should have the same weight, however its inclusion should not be forced by any means, as a way to prevent its faulty articulation.

Still, they denoted how difficult or tricky it can be to highlight the Arts and incorporate them in the way they deserve and that makes the best sense, due to the strictness of the curriculum and the lack of training and preparation of the educators.

It is part of life and of being human to know that just because something should be done in a specific way, it does not mean that it happens that way. It is the same for STEAM education and particularly for the way the 'A' is concluded. Thus, questioning the specialists on their opinion about the gap existent (or not) between **how the 'A' is being included in STEAM and how it should be included** seemed imperative.

How the 'A' is being included in STEAM

One expert, expert E, highlighted the fact that most schools in Europe do not practice STEAM, let alone consider the inclusion of the Arts in the STEM areas. This shows how most educational institutions, especially public ones, are still living the traditional and highly segregated curriculum, where subjects do not communicate with each other.

For the schools that do practice STEAM, or try to, there is a very reductive inclusion of the Arts and Humanities. This translates into, for example, embellishing or painting a robot. It does not bring much to the conversation and therefore it does not showcase the artistic importance to students.

How the 'A' should be included in STEAM

Regarding this aspect, five main answers arose:

- Ideally, according to an expert, the Arts should be included since the very beginning of a project or an activity by being part of a problem's essence and context, being a lot more than just the visual component.
- According to another expert, STEAM-implementing schools should strive for more projects and activities that allow the collaboration between Design-Thinking and real-problem solving.
- Generally, most agreed that the Arts should be viewed more broadly, by including the Humanities in the context and essence of a given project.
- They all agree with the idea that schools' curricula should be adjusted in order to accommodate the STEAM pedagogy.
- Another relevant idea mentioned is the need to give teachers freedom to see their subjects in a wider spectrum and teach them in a way that includes and highlights the STEAM philosophy.

It is clear in the readings that both STEAM and educational robotics are hard to implement in today's European school curricula. Because each country has its differences and specificities, it was vital to query experts on their opinion of **the biggest hurdles to these implementations**. Several possibilities emerged, but the one where five (Experts A, B, C, E, and F) of them agreed on was the official curriculum. There is a belief that there is a severe disconnection between the contents being taught in each class and the world outside students' experience. This same disconnection often makes the collaboration between

teachers and their subjects harder, or even impossible. This can be due to the lack of flexibility and adaptability that characterises most curriculums around Europe, as well as the lack of funding of these type of innovative initiatives (experts B, C, and F).

Teacher training was also brought up by more than half of the experts, as well as the cost of technology that along with lack of funding and overall money makes it harder for schools to implement STEAM (experts A, B, C, D, E, and F).

One professional highlighted something also noticeable in the literature that is the lack of material and guidelines for teachers and schools to implement STEAM activities or incorporate them in "regular" classes (expert D).

Another difficulty is the fact that designing a curriculum that aims to accompany kids for several years of their school path is daunting and has no precedents. So, it is a trial-and-error process that can cause loss of money, time, and overall affect the performance and success of the students and of the STEAM implementation (expert D).

Specific to one of the countries, Portugal (expert F), is the grade-oriented school system, that benefits memorisation and test scores over knowledge acquisition. This leads students to focus normally on STEM subjects, as it is what is seen as promising and valuable, in detriment of the skills they garner in artistic and humanistic subjects.

Questioning them about this dissertation's main research question – ***What is the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?*** – they all felt intimidated as there are not enough years of experience to back different approaches. Still, they all gave their input based on their experience teaching STEAM and implementing or not using Robotics.

They all agreed that one of the best ways to include the 'A' in STEAM with (or without) Robotics is by creating a project or activity where the students are involved in every step of the way, from the research about the given theme or subject, to the presentation and "selling", if it is a product.

They underlined the importance of not neglecting the Arts and Humanities component and what it can bring to the table, but at the same time not forcing it in every step of the process by only integrating it where it makes natural sense, for example, in the context and essence of the project.

One specialist, expert F, stressed that it will not be possible to include every single letter of STEAM in every project and have them carry the same weight. He advised that one should understand this fact and try to thoughtfully and strategically involve the areas that

make sense and articulate them the best way possible. Expert A defends that introducing Robotics in early childhood as part of Fine Arts is what enhances its benefits to students.

Another expert, expert E, highlighted that one crucial aspect to ideally implement STEAM is through supporting teachers and investing not only money, but also time in training and educating them.

The idea of creating competitions and initiatives outside of the school curriculum pertaining to STEAM or STEAM & Robotics can trigger students' interest and curiosity, which, consequently, can make the transition in the official curriculum much easier.

One very interesting contribution was given by expert A, who recommended the creation of competence levels (like in foreign language classes, for example, German A1.1., German A1.2., and so on) in order to promote a better and easier adjustment of both technical and soft skills, so the shift and pace is adequate to the students' degree of knowledge.

Other decisions lie with stakeholders, such the Ministries of Education and school boards, in order to garner the necessary amount of money to fund STEAM activities and the required power to change and modernise the curricula.

Finally, expert E gave two potential solutions to this question when answering the one about the role of Robotics. He shared his experience of working with his students on a LED wand. They built the LED strip and programmed the Arduino in the Computer Science class, and in the Arts and Crafts class, they used it to do light painting. Therefore, they got the technical experience, and added knowledge in how to work a camera and better their artistic expression. Additionally, and to conclude this, he shared another project where students had to construct a robotic hand for people who are missing a limb, a similar example was seen in literature (Bush & Cook, 2019). First, they started with the language part, by reading and learning about people with this type of disability, what a surgeon does, what a prosthetic can do, and so on. Second, they brainstormed what they could do to help them. And following this, in the practical disciplines, they designed the robotic hand, built it, programmed the Arduino, and in the end made the necessary adjustments. At the end of project, they also reflected on the importance of prosthetics, specifically automatised ones, in healthcare.

Regarding the specific **critical incidents and behaviours** identified by the professionals, the table below organises and synthesises them.

Having in mind the prior planning to the collection of data, it was vital to identify critical incidents and potential critical behaviours that had anything to do with and contribute towards:

- The implementation of STEAM education in Europe;
- The use of Robotics in schools;
- And the inclusion of Arts & Humanities in STEAM education.

As Flanagan (1954) himself concedes, this is a fairly subjective step, as it depends on the kind of information given by the interviewees and the objective of the study. Given the scope of this dissertation, which is inscribed in a master's degree, it was of the essence to follow along the literature's guidelines, but adapt them, as the creator himself, Flanagan, allowed, to the goals and purposes of the research in question. Therefore, the categorisation of the critical incidents and behaviours (listed in the table below) is much simpler than a traditional and lengthy investigation would produce. Nevertheless, the incidents were identified as well as key behaviour that contribute to help solve the three research questions posed in the beginning of the research.

Table 14 – Critical incidents and behaviours

Critical incidents	Critical behaviours
COVID-19 has made STEAM implementation more difficult because it often requires connection and collaboration	- Come up with solutions to continue the implementation of STEAM virtually or presently, but in a safe way.
Recognising that there are almost no suitable guidelines and teaching materials for all ages comprised in K-12	- Invest and fund teacher training and research as well as experiments to further the development of knowledge in this area of education.
Incorporating STEAM in every "regular" class	- Make sure it is done in a natural way and that it not only serves aesthetic purposes. - Teacher collaboration. - Create a bridge between the content taught and its applicability in the real world.
Incorporating Robotics in "regular" classes	- Stress how Robotics can be a gateway for other complex technology and initiate the much-needed shift in traditional education. - Foster the conversation regarding the relationship between humankind and machines (technology in general).
Investing money/Funding STEAM initiatives to support teacher training, technology costs, etc.	- Continue research to prove the results and benefits of STEAM education.

	- Sensitize stakeholders, key-people, policy makers, and so on, to the imperative nature of this new form of pedagogy.
STEAM implemented as a separate subject	- Although not in concordance with its essence, it is successful if teachers create and curate attractive and lengthier projects that one could not do in "regular" classes.
Stiffness of the official curriculum	- Sensitize stakeholders, key-people, policy makers, and so on, to the imperative nature of this new form of pedagogy, and demand for changes/adaptations in the curriculum.
Creation of a STEAM track in the official curriculum and have STEAM incorporated into "regular" tracks, which is easier in private schools, where principals have more autonomy and agency over the curricula being taught	- Sensitize stakeholders, key-people, policy makers, and so on, to the imperative nature of this new form of pedagogy, and demand for more agency to act according to the school's environment and context.
Fostering STEAM instead of STEM education because it appeals much more to girls, and it is necessary to have their contribution to build the future	- "Market" STEAM as an approach to STEM education that also highlights the artistic and humanistic part of knowledge

This method, unlike the previous one, did not aim at reaching a level of consensus, but understanding the personal experience and opinions of experts in their own words. It is clear by the data amassed, that although no specific numbers are gathered to prove one answer or factor to be more valid than another, the interviews allowed for a better framework not only of the experts but of the current status of STEAM education and educational Robotics in Europe. It was easier to see and comprehend the reasoning behind the participants' answers as they followed them with examples and explanations through recalling specific incidents and behaviours, as well as the personal reflection they made on it.

3.3. Results

This subchapter focuses on the presentation and discussion of the answers to this dissertation's research questions, which resulted from the triangulation of the information amassed from both research methods – Delphi Method & Critical Incident Technique – and the literature read.

3.3.1. How are European schools implementing STEAM (with Robotics)?

The first (auxiliary) question aimed at understanding the current landscape of the STEAM pedagogy implementation in European schools, specifically K-12.

It is clear from the sample of experts questioned on these matters, that STEAM education is being implemented in Europe with and without Robotics. This validates the readings which stated there have been multiple initiatives in the last few years to stimulate the integration of this new form of pedagogy in official European curricula (Manera, 2020). Even more, the accounts given by the experts also confirm that although the implementation is slowly being done, it is far from easy (Christensen & Knezek, 2015; Conde *et al*., 2021).

What is also evident is that STEAM is being more implemented on its own than with Robotics. Some of the experts, less than half, had had some actual experience regarding STEAM and Robotics combined in their work environment, while the majority's recounts were from a theoretical point of view, and not from a practical one. Still, they are all aware of the relevance Robotics and its "easiness" to articulate with STEAM, even with the Arts and Humanities component.

3.3.2. What do experts and practitioners say on the current inclusion of the 'A' in STEAM and on how it should be included?

The second (auxiliary) question pertains to the data collection done with both Delphi Method and CIT experts, because it intended to understand their professional and personal opinion on how the 'A' in STEAM is being included *versus* how it should be included.

One important facet of this question relates to what one believes the 'A' in STEAM to stand for, because this directly influences the way STEAM is implemented and how the inclusion of the Arts in STEM is perceived. By looking at what literature has to say on this matter, along with what the experts provided, there is no clear consensus. The basis is evident: the 'A' in STEAM stands for the Arts, it is their wide range of disciplines and meanings that lead people to confusion. From the subjective analysis done of the readings and the experts answers to this dissertation's queries, the clear thought, even if subconscious, is that the 'A' stands for the Arts in a general sense. Therefore, it encompasses the Humanities, and it is their inclusion in the realm of STEM allows for the development

of skills such as creativity (one of the most talked about), critical thinking, collaboration, problem-solving, and so on. This integration can be of help of techniques such as Design-Thinking, which gained a *rough* consensus among the Delphi Method experts, where seven out of the eight remaining experts agreed to be included in the 'A' in STEAM. Hence, based on the readings and the data collected, it is fairer to assume and propose the 'A' to encompass both the Arts, in a Fine Arts sense, and the Humanities, which together and articulated with the areas of knowledge present in the STEM acronym foster competencies in design-thinking, creativity, self-awareness, empathy, and so on.

Specifically, regarding the current implementation in STEAM, it is clear from the experts' recounts, that STEAM is indeed being implemented in the European context, but it is still in a very embryonic stage, as most schools and students are not exposed to this new form of pedagogy. Another point determined is that STEAM is being implemented mostly without Robotics, as a result from the lack of funding and teacher training. It is also being introduced into schools' curricula via subjects such as Design-Thinking, very commonly mentioned by the experts from Belgium, or subjects named STEAM. This last proposal is not ideal by the means of any experts' opinions and is also noted in literature as defeating the purpose of the concept itself. STEAM, as mentioned throughout this dissertation, originated from the inclusion of the Arts in the acronym STEM, i.e., the articulation of the technical disciplines with the artistic and humanistic ones. Thus, it is born out of the conversation and collaboration between different areas of knowledge. With this in mind, it seems discernible that STEAM can only be properly implemented if it is perceived as the dialogue between all existing disciplines and not as a new discipline itself. Nevertheless, experts highlighted the lack of curriculum and time flexibility, which hinders the inclusion of the STEAM essence in the traditional classes. That is why, one of the experts (expert F from the CIT), agreed that a good compromise would be to include the essence of STEAM in the already existing curriculum, and create an additional hour in the schedule to dedicate to the development of STEAM related projects and activities.

As a means of making this happen, of turning what it should be into what it is, some things need to shift or continue to adapt. More investments have to be allocated into research, teacher training, and production of specific, yet adaptable, starting guidelines to implement STEAM in schools. This way, it is easier for educators to apply a certain model to their school and its necessities and environment. Teachers around the world, and schools in general, have to continue their communication and sharing of practices, this way fostering

the STEAM essence and the more rapid construction of tangible and quantifiable knowledge regarding STEAM education.

One thing is clear and indisputable from the very start, in literature and in the experts' opinions: the stimulus for the implementation of STEAM in education is a demand and necessity to prepare the students of today, the adults of tomorrow, for the ever-changing world that awaits them. Thus, governments, schools, educators, parents, and students need to be sensitised about the value of STEAM education and the imperative character its implementation has in our current world. Besides preparing them for the future, in terms of profession and skills, STEAM also aids in preparing students to become better citizens and members of society.

3.3.3. What is the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?

The primal research question for this dissertation, expected to help emerge one possible solution for the ideal inclusion of the 'A' component in STEAM K-12 education with the specific example of Robotics (to make the explanation more tangible). This was only possible to respond to with the help of the answers to the two previous questions, the interactions made with the study participants, plus the information gathered from the literature review.

What is key and common to all experts' opinions is that it should be included from the very beginning, as part of the essence and context of the project or activity. This way we minimise the risk of using the Arts component just for embellishment or as a way to serve the other areas included in STEAM. As for Robotics, as can be seen in literature and with the experts' beliefs, its inclusion in an educational environment helps foster the reflection on its artistic and humanistic facets. Consequently, it is the *perfect* area of technology to collaborate with STEAM.

The most substantiated example was found in literature (Bush & Cook, 2019) and reinforced by most experts, specifically one, expert E from Belgium, who participated in the CIT interviews. It helps prove the idea shared by the professionals that, ideally, STEAM should not be implemented as an additional subject, but as a collaboration between all the existing ones. The following steps encompass the most tangible and palpable solution to this question achieved in this investigation:

1. Find a theme that students can connect to and/or find relatable.

For example, a student/colleague who suffers from some disability or problem.

2. Stimulate the students, in the appropriate classes, to do the research concerning the theme of the project.

   For example, if the project is about constructing a robotic arm for a person who is missing a limb, as exemplified by the book chapter (Bush & Cook, 2019) and expert E, Science teachers can discuss anatomy and health questions regarding this, Language teachers can share testimonies and read texts written by people who suffer from this type of problem, History teachers can go through historical figures who also had disabilities and discuss how these could have impacted their lives, and so on.

3. In the Arts or Design class, prompt the students to come up with innovative and practical solutions to the design of the arm, considering the person who is going to use it and their requirements.

   For example, talk to the person they will be building the arm for, encourage them to try to for one day go about without using their main arm, research different types of designs and their usages, etc.

4. In a Computer Science or Robotics class, build the arm, and programme it.
5. With finish the "product" in a way that looks appealing to the person who will be using it, without diminishing its practicality.
6. In the end, try it out and see what can be bettered before giving it to the target person.
7. After the completion of the project, talk with the recipient of the product/solution and question them on what could have been better and how it has impacted their lives. It would also be beneficial for teachers to assess their students in the areas they covered their subjects, in order to comprehend if knowledge were successfully acquired or not.

The justification behind this solution lies on its fairly easy application, and the combination of the school environment with the community where it exists.

It is, of course, a task that could be made simpler if schools, teachers, and students, like the experts agreed, were given the freedom to implement STEAM in a way that best suits the necessities of their said environment. As official curricula continue to be overflowing with contents, a good compromise would be to have a subject that did not teach

STEAM but helped bridge all the “regular” classes and oversee projects like the one mentioned above.

4. Conclusion

Primarily, this dissertation aimed to shed light on the themes that most affect our present and will continue to affect us in the future. Mainly, it focused on the exploration of the Arts and Humanities, STEAM education, and educational robotics. It intended to bring more awareness to the urgency of modernising education so it can better prepare students for the global economy and society of the 21st century. This includes understanding what is and how can STEAM education help achieve that, what kind of role and how the Arts and Humanities can help, and in what way Robotics can be added as a means to foster a better relationship between humans and complex machines/technology.

Besides a hefty literature review, which expanded on all three main subjects of this dissertation, two research methods – Delphi Method & Critical Incident Technique – were applied in order to better answer the three research questions:

- What is the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?
    - How are European schools implementing STEAM (with Robotics)?
    - What do experts and practitioners say on the current inclusion of the 'A' in STEAM and on how it should be included?

After understanding the theoretical framework where the three primal themes were inserted, the data collection began twofold. Delphi Method questionnaires were deployed to ten initial experts, and a rough consensus was reached after three iterations:

- The 'A' in STEAM stands for the concepts of design and design-thinking.
- The inclusion of the Arts and Humanities in STEAM is done in order to prepare students for the challenges of today's world and the future that awaits them.
- The inclusion of the Arts and Humanities in STEAM should be done not as a separate subject but included in the already existing ones.
- And, what most contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics is the freedom for schools, teachers, and students to implement STEAM the way it best suits their necessities.

And six CIT interviews were conducted where much information was amassed, and rich ideas came to corroborate literature and expand the knowledge concerning these subjects. The main critical incidents identified were the following ones:

- COVID-19 has made STEAM implementation more difficult because it often requires connection and collaboration.
- Recognising that there are almost no suitable guidelines and teaching material for all ages comprised in K-12.
- Incorporating STEAM in every "regular" class.
- Incorporating Robotics in "regular" classes.
- Investing money/Funding STEAM initiatives to support teacher training, technology costs, etc.
- STEAM implemented as a separate subject.
- Stiffness of the official curriculum.
- Creation of a STEAM track in the official curriculum and have STEAM incorporated into "regular" tracks, which is easier in private schools, where principals have more autonomy and agency over the curricula being taught.
- Fostering STEAM instead of STEM education because it appeals much more to girls, and it is necessary to have their contribution to build the future.

Ultimately, the final thesis, i.e., the results proposed are that:

- STEAM education is indeed being implemented in Europe with and without Robotics. It is being done mostly via projects and disciplines such as Design-Thinking.
- The experts agree there is a gap between how the 'A' is being included in STEAM and how it should be included. Although most experts see the inclusion through Design-Thinking, their thought process, and answers, along with the readings, suggest the ideal way of including the 'A' is through encompassing both the Arts and Humanities as they are proven to foster the skills they desire and that the students and next generation's needs, i.e., creativity, critical thinking, and so on. This should be done via the dialogue between existing subjects, and not through the creation of a subject called STEAM.
- A tangible example that would perfectly include the 'A' in STEAM K-12 education with Robotics lies in the execution of a project with very specific

guidelines that involve the students and their disciplines in different steps of the process, from the brainstorming, through research, culminating in "client's" satisfaction.

Beyond the answers produced to answer the research questions, much knowledge was gathered that can be useful to both researchers in any of these three areas and practitioners specifically in STEAM education and educational robotics. Although much was achieved in such short amount of time, much more could be have been done. Both methods chosen were adequate and provided rich data and an interesting form of collecting it. However, given their complexity, it would have benefited from more research time, in order to religiously follow all the guidelines and rules. Losing two experts after the First Delphi Questionnaire was not ideal and it did compromise and delay the further questionnaires, however, it is believed the rough consensus is of use and as rigorous as it could be. Additionally, it would have been advantageous to conduct follow-up interviews with the Delphi Method experts in order to further contextualise their answers and better understand their context.

Nonetheless, it is believed that the final product of this dissertation is satisfactory and helpful to not only academics, but as stated before, practitioners. It has fulfilled its goal to further the knowledge concerning these questions, as there were no recounts in the readings pertaining to investigations along the same lines as this one (combining both literature and experts/practitioners), and hopefully brought more awareness to the topics of STEAM education and educational robotics, that continue to gain force, but are still widely misunderstood and undervalued.

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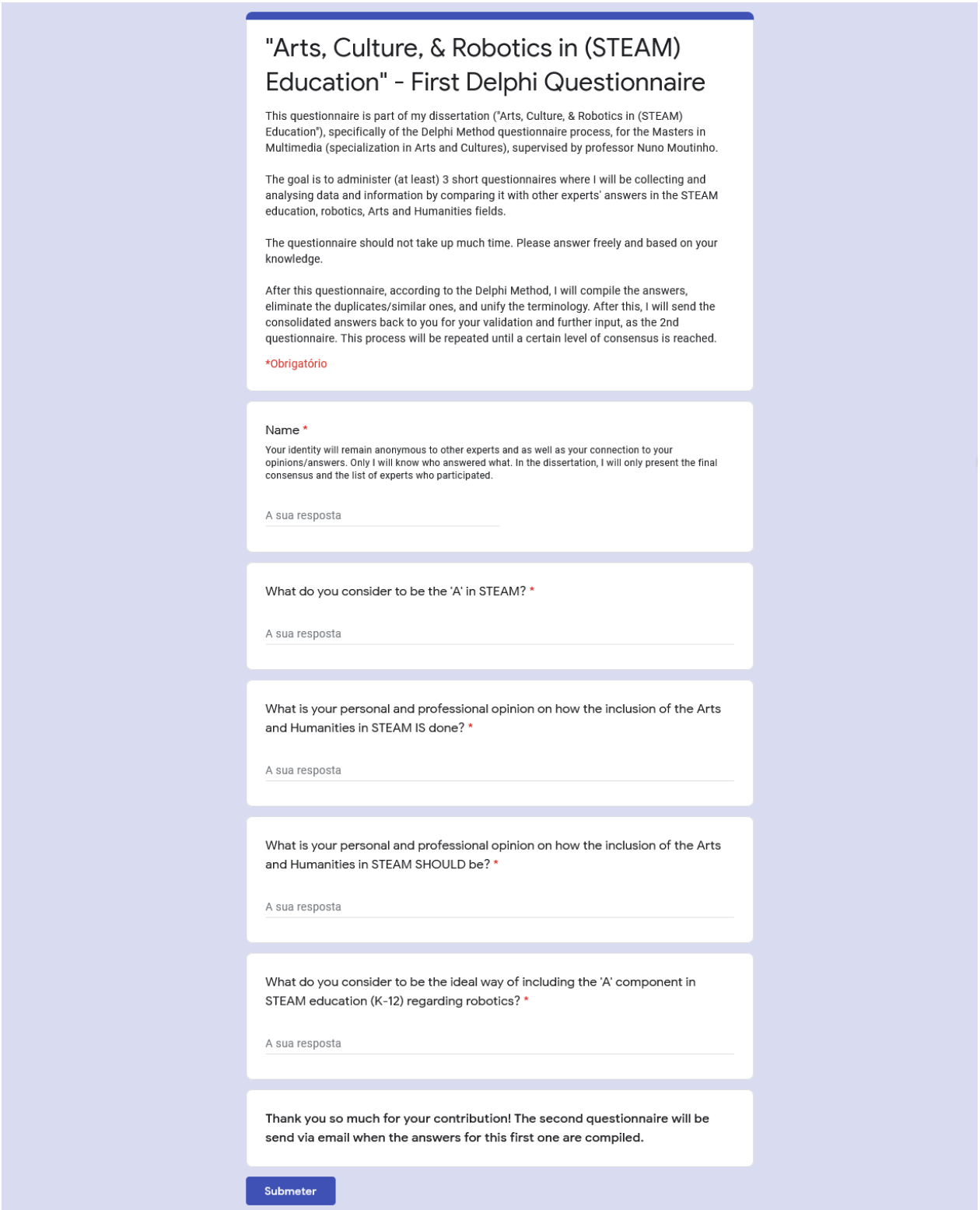
7. Annexes

7.1. Delphi questionnaires

Annex 7.1.1. – First Delphi Questionnaire



"Arts, Culture, & Robotics in (STEAM) Education" - First Delphi Questionnaire

This questionnaire is part of my dissertation ("Arts, Culture, & Robotics in (STEAM) Education"), specifically of the Delphi Method questionnaire process, for the Masters in Multimedia (specialization in Arts and Cultures), supervised by professor Nuno Moutinho.

The goal is to administer (at least) 3 short questionnaires where I will be collecting and analysing data and information by comparing it with other experts' answers in the STEAM education, robotics, Arts and Humanities fields.

The questionnaire should not take up much time. Please answer freely and based on your knowledge.

After this questionnaire, according to the Delphi Method, I will compile the answers, eliminate the duplicates/similar ones, and unify the terminology. After this, I will send the consolidated answers back to you for your validation and further input, as the 2nd questionnaire. This process will be repeated until a certain level of consensus is reached.

*Obrigatório

Name *

Your identity will remain anonymous to other experts and as well as your connection to your opinions/answers. Only I will know who answered what. In the dissertation, I will only present the final consensus and the list of experts who participated.

A sua resposta

What do you consider to be the 'A' in STEAM? *

A sua resposta

What is your personal and professional opinion on how the inclusion of the Arts and Humanities in STEAM IS done? *

A sua resposta

What is your personal and professional opinion on how the inclusion of the Arts and Humanities in STEAM SHOULD be? *

A sua resposta

What do you consider to be the ideal way of including the 'A' component in STEAM education (K-12) regarding robotics? *

A sua resposta

Thank you so much for your contribution! The second questionnaire will be send via email when the answers for this first one are compiled.

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Annex 7.1.2. – Second Delphi Questionnaire

"Arts, Humanities, & Robotics in (STEAM) Education" - Second Delphi Questionnaire

Welcome to the 2nd Delphi Questionnaire!

Thank you once again for your willingness to collaborate in this master's dissertation.

The present questionnaire aims to:
- validate your answers from the 1st questionnaire (as you can reiterate them by choosing the options that relate to your initial answers)
- refine the answers given by all experts in order to achieve a growing consensus
- allow you to include additional information you find pertinent

For each question you can choose more than one option. You choose according to what you consider to be the best answers for the 4 main questions.

You can see the answers you gave in the first questionnaire through the document sent via email. You may change your mind and respond differently in the present questionnaire.

If you want to answer something that has not been said before, please use the "Other option" option.

If you have something to say regarding the theme of the dissertation, but it does not fit the 4 main questions, please use the last text box to share your opinion.

Please answer as soon as possible :)

*Obrigatório

Name *

A sua resposta

What is the 'A' in STEAM? *

- [ ] Design/Design-thinking
- [ ] Visual Arts/Aesthetics
- [ ] Creativity
- [ ] Humanities/Liberal Arts
- [ ] Outra:

How is the inclusion of the Arts and Humanities in STEAM done? *

- [ ] Still very recent
- [ ] The theory vs. practice is still, generally, very different
- [ ] There are growing efforts to implement it in schools' STE(A)M curricula
- [ ] Mostly done by individual teachers
- [ ] Often reductory (for embellishment purposes or just for the sake of it)
- [ ] The inclusion of STEM in the Arts is easier than the Arts in STEM
- [ ] Slowly, because people fear the technological aspect
- [ ] Slowly, because some people see the value in it and others do not
- [ ] In order to prepare students for the challenges of today's world
- [ ] Not just technology based
- [ ] In a way that attracts a lot more girls than STEM
- [ ] Outra:

How should the inclusion of the Arts and Humanities in STEAM be done? *

- [ ] The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- [ ] The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- [ ] STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- [ ] It should be a part of every school's curriculum
- [ ] Schools and teachers should have the freedom to be able to best implement it at their given context
- [ ] By providing teacher training and teaching material
- [ ] Through grassroot projects
- [ ] Through school projects and activities
- [ ] As a separate subject from the other ones
- [ ] Not as a separate subject, but included in the already existing ones
- [ ] From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
- [ ] Students should have prior programming knowledge so it can be better applied
- [ ] Outra:

How should the inclusion of the Arts and Humanities in STEAM be done? *

- [ ] The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics
- [ ] The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way
- [ ] STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)
- [ ] It should be a part of every school's curriculum
- [ ] Schools and teachers should have the freedom to be able to best implement it at their given context
- [ ] By providing teacher training and teaching material
- [ ] Through grassroot projects
- [ ] Through school projects and activities
- [ ] As a separate subject from the other ones
- [ ] Not as a separate subject, but included in the already existing ones
- [ ] From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)
- [ ] Students should have prior programming knowledge so it can be better applied
- [ ] Outra: _____

What contributes to the ideal way of including the 'A' component in STEAM education (K-12) regarding robotics? *

- [ ] Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities
- [ ] Use the 'A' to stimulate students to question and think about the outlook on robotics (how it fits into our society, what rules should it follow, etc.)
- [ ] The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system
- [ ] The robots as tools to enhance interactivity
- [ ] The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)
- [ ] Teachers determining the robots/robotics' artistic and humanistic learning goals in order to enhance their usage
- [ ] Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum
- [ ] Robots/robotics as a way to address more complex issues from technical, societal, and individual points of view, including ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
- [ ] Outra: _____

Write here any additional information you would like to share that does not fit into the questions above (OPTIONAL)

A sua resposta

Thank you so much for your contribution! The third, and most likely final, questionnaire will be sent when all experts have responded and the information synthesised, hopefully until the end of this week/beginning of the next.

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Annex 7.1.3. – Third Delphi Questionnaire

"Arts, Humanities, & Robotics in (STEAM) Education" - Third Delphi Questionnaire

Welcome to the 3rd and last Delphi Questionnaire!

Thank you once again for you time and contribution.

The present questionnaire aims to:
- validate your answerss from the 2nd questionnaire
- rank the answers given by all experts in order to achieve a certain level of consensus

For each question, please rank the answers you consider to best answer the given question. 1 is the highest you can rank an answer. You only have to rank the options you consider to answer the question, if there are options that you don't agree with, you don't have to select them, just leave them blank.

Please answer as soon as possible and until Sunday, June 20th :)

*Obrigatório

Name *

A sua resposta

What is the 'A' in STEAM?

	1	2	3	4
Design/Design-Thinking	○	○	○	○
Visual Arts/Aesthetics	○	○	○	○
Creativity	○	○	○	○
Humanities/Liberal Arts	○	○	○	○

How is the inclusion of the Arts and Humanities in STEAM done?

	1	2	3	4	5	6	7	8	9
As something still very recent	○	○	○	○	○	○	○	○	○
The theory vs. practice is still, generally, very different	○	○	○	○	○	○	○	○	○
Mostly done by individuals	○	○	○	○	○	○	○	○	○
In a reductive way (as a way to embellish/does not contribute with something of value)	○	○	○	○	○	○	○	○	○
There are growing efforts to implement STE(A)M in schools' curricula	○	○	○	○	○	○	○	○	○
Including STEAM in Arts is easier than including the Arts in STEM	○	○	○	○	○	○	○	○	○
Slowly, because some people fear the technological aspect	○	○	○	○	○	○	○	○	○

Slowly, because some people see the value in it and others do not	○	○	○	○	○	○	○	○	○
In order to prepare students for the challenges of today's world and the future that awaits them	○	○	○	○	○	○	○	○	○
Not by just including technology into the regular school's curriculum	○	○	○	○	○	○	○	○	○
In a way that attracts more girls into STEM	○	○	○	○	○	○	○	○	○

How should the inclusion of the Arts and Humanities in STEAM be done?

	1	2	3	4	5	6	7	8	
The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics	○	○	○	○	○	○	○	○	
The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	○	○	○	○	○	○	○	○	
STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)	○	○	○	○	○	○	○	○	
It should be a part of every school's curriculum	○	○	○	○	○	○	○	○	
Schools and teachers should have the freedom to be able to best implement it at their given context	○	○	○	○	○	○	○	○	
By providing teacher training and teaching material	○	○	○	○	○	○	○	○	
Through grassroot projects	○	○	○	○	○	○	○	○	
Through school activities/projects	○	○	○	○	○	○	○	○	
Not as a separate subject, but included in the already existing ones	○	○	○	○	○	○	○	○	
From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	○	○	○	○	○	○	○	○	

What contributes to the ideal way of including the 'A' component in STEAM education (K-12) regarding robotics?

	1	2	3	4	5	6	7	8
Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities	○	○	○	○	○	○	○	○
Use the 'A' to stimulate students to question and think about the outlook on robotics (how it fits into our society, what rules should it follow, etc.)	○	○	○	○	○	○	○	○
The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system	○	○	○	○	○	○	○	○
The robots as tools to enhance interactivity	○	○	○	○	○	○	○	○
The use of robots in both visual and performing arts (eg. theatre with robots, fashion shows with robots, etc.)	○	○	○	○	○	○	○	○
Teachers determining the robots/robotics' artistic and humanistic learning goals in order to enhance their usage	○	○	○	○	○	○	○	○
Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum	○	○	○	○	○	○	○	○
Robots/robotics as a way to address more complex issues from technical, societal, and individual points of view, including ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators	○	○	○	○	○	○	○	○

Thank you so much for your contribution!

The final dissertation will be sent to you in end of July so you can see how your contribution played a part :)

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7.2. Delphi Method data collection results (summary)

Annex 7.2.1. – First Delphi Questionnaire Results Summary

What is the 'A' in STEAM?	
EXPERT 1	- Creativity
EXPERT 2	- Design-Thinking
EXPERT 3	- Arts
EXPERT 4	- Arts & Humanities
EXPERT 5	- Arts
EXPERT 6	- Arts, Design-Thinking, & Humanities
EXPERT 7	- Arts & Creativity
EXPERT 8	- Arts
EXPERT 9	- Arts & Humanities
EXPERT 10	- Arts & Design-Thinking
How is the inclusion of the Arts and Humanities in STEAM done?	
EXPERT 1	- Via school projects and other cooperative projects, such as Erasmus+. - Implementing STEAM is hard because the official curriculum is overflowing. - It is important to show students the value STEAM brings them, by taking what they learn in school to the outside world.
EXPERT 2	- STEM is totally different from STEAM and adding the Arts and Design-Thinking techniques makes the whole model flourish and prosper. - Many teachers and art teachers are interested in participating and organising STEAM modules in his particular school.
EXPERT 3	- The inclusion of the 'A' is the biggest challenge after the technical development, as a lot of people are still scared of certain aspects of complex technology (impacts in society, jobs, etc.). - It should be an ongoing discussion not only in schools, but outside of them, and even between professionals and intellectuals and "regular" people.
EXPERT 4	- The Arts and Humanities are still not being properly included in the planning and/or application of activities/projects. This can be due the lack of training, misconceptions about STEAM, or even logistic inability. - The superficial application of the 'A' conveys to students that this component is not as important and as valuable/useful as the other areas in the acronym.
EXPERT 5	- It is not always easy to include the Arts and Humanities in STEM, but it is easier to include STEM in Arts. - Sometimes, the implementation of the Arts in STEM education feels unnatural and the first loses its relevance. - However, good examples should be sought for because transfer of knowledge is crucial.

	- Art can be useful to make learning material visible to students, as often is difficult to do in STEM subjects.
EXPERT 6	- Arts and Humanities are being introduced in STEM due to the demand economy and society have for well-rounded individuals and professionals. Therefore, the educational sector had to adapt to what is and will continue to be required of its students.
EXPERT 7	- STEAM is a relatively new concept and has yet to be incorporated into everyday school life. - There are some schools that implement STEAM successfully, but it comes more from the initiatives of individual teachers. - There are some frameworks and guidelines provided, however, in practice, they often do not apply.
EXPERT 8	- The Arts are always present, especially when it involves designing a model or something of this sort, but teachers do not always recognise that they are almost always inherent to every subject/theme.
EXPERT 9	- In her specific context, the 'A' is emphasised a lot in STEAM education, because it is the foundation of STEAM.
EXPERT 10	- Now it is not just technology based, it is much more. It is easier to "sell" it to teachers, students, and parents, because girls are much more interested in doing things with complex technology because the perspective brought by STEAM is completely different.
How should the inclusion of the Arts and Humanities in STEAM be done?	
EXPERT 1	- We are on the right track to integrate the Arts and Humanities in STEAM, although it is not an easy task. - Students often need prior knowledge before starting certain projects, so the implementation is easier (e.g., programming). - It should not be separated as another subject but incorporate through projects in the "regular" classes, although there is the problem of the overflowing curriculum.
EXPERT 2	- Art should play a big role not only in education, but in the future, however, it does not matter if one emphasises the 'A' or not. What is important is that the 'A' is included when it makes sense.
EXPERT 3	- STEAM should be a very important part of education because it will provide them the right knowledge and tool to be part of the 21st century society and economy.
EXPERT 4	- It should be made from the ground up, i.e., included in the context and essence of a given project or activity, or even as a form of expression (e.g., dance). - The 'A' should aid the purpose and direction of what is meant to be created, therefore, teachers can plan their activities in a way that allows for the discussion of cultural impact, sensibilities, and perceptions. Students' background and

	ethnicity can be interesting to explore in order to understand and cultivate empathy. - In order to achieve this, it is crucial to invest in teacher training.
EXPERT 5	- In an ideal world, the Arts would not only be approach in an integrated way, but also in an interdisciplinary and transdisciplinary way.
EXPERT 6	- The integration of the 'A' in STEM is happening more naturally in the business sector because there is a palpable consequence, which is growth and profit. In education, because the results are not tangible and cannot be seen immediately, the 'A' is being implemented in a multitude of ways or not at all. - Education officials and policy makers should observe what is being done in the business sector and adapt it to education. There is a need to train teachers and create environments where students can be exposed to real life problems and prompted to create strategic solutions to address them.
EXPERT 7	- These ideas can only come to fruition if teachers are given the necessary freedom to go beyond the official curriculum. This can only be achieved via teacher training and good teaching materials. Practical ideas are also necessary. - Schools also need more freedom to foster their individual strengths and act according to their environment. Plans that are imposed from people who do not know the specific reality often do not work. - There is a need for more grassroots projects that are anchored to the school environment and also more cooperation with extracurricular educational institutions.
EXPERT 8	- The Art component is already present, but awareness needs to be raised with teachers so they can acknowledge the 'A' as being an equally important part of the acronym. This way, they will be able to better highlight it to students in projects and to include it in the assessment.
EXPERT 9	- In many cases, STEAM is often seen as a "hard" subject because it only focuses on the technology, engineering, and math part of it. It would be very beneficial to emphasise the "soft" side of STEAM which is brought by the Arts (creativity, well-being, etc.)
EXPERT 10	- In his environment, in design projects, the Arts and Humanities are as important as the Mathematics and Engineering, for example. That is why he considers everyone at his school believes the STEAM projects are one of the most important things in the curriculum.
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	

EXPERT 1	- STEAM education should be seen as much more than Robotics, and we should try to understand what one means by Robotics, so it is easier to implement. - Instead of focusing all attention on students learning programming or other "hard" skills, we should focus on seeing the bigger picture. - A lot of "regular" teachers and arts teachers are interested in participating and organising.
EXPERT 2	- The 'A' can be articulated with Robotics by prompting students to think about the outlook on Robotics (e.g., the purpose of robots, how to handle them, how do they fit in our world, etc.).
EXPERT 3	- By prompting students to reflect and discuss about the opportunities and risks Robotics carry.
EXPERT 4	- Robotics in education has seen a boom in the last years, because the industrial and educative sectors understand its prevalence in future professions, and in the future overall. - Robots can be articulated with Arts to achieve new and creative methods of expression. - Robots are tools that allow a new and ground-breaking level of interactivity, and as tools their role is to facilitate processes. - We should consider robots as future dance partners and performative artists. - Teachers should experiment, observe, and write down the results in order to understand the impact in students' education and skill development.
EXPERT 5	- The 'A' and Robotics seem unrelated at first sight, but it is true both domains can take each other to a higher level. - Robotics can be a facilitator to bring STEAM into education. - An example of application can be a camp, like Artbot, which is a 3-day initiative for primary school students. It aims at fostering the contact between the pupils and Arts and Robotics. Pupils work on a theme and programme their own robot to perform some art form (e.g., painting, reciting a poem).
EXPERT 6	- Robotics can be the perfect instrument to introduce challenges and problem-solving in K-12 education. - Robotics can be used to address complex issues regarding the technical, individual, and societal perspectives, by including Ethics as a way to have students understand the complex role technology has in our lives and what kind of roles they can have as potential future creators of technology.
EXPERT 7	- It would be interesting to have a group of people interested in Arts or a cultural group meet with students at school. It is important to foster students' relationship with their community as, for example, having them talk to older people and understand how loneliness affects their age group and if

	they think a robot companion would be of help. They could then work with artists to think about the design of this robot and create them in a way that makes sense to who is going to be around them. This way, students are broadening their horizons, connecting with their community, and applying what they are learning in school to live real life situations. In order for this to happen, schools need to become more open to their own community and potential external partners.
EXPERT 8	- It is difficult to say given that it almost always present (when students design a solution, think about the model, the materials, the shape, weight, and so on). In the engineering part of the project Art is always present. The same goes for the presentation of a project (the PowerPoint presentation, the artistic components and styles used, the colours, fonts, photos, etc.)
EXPERT 9	- It is necessary to have a lot of freedom to design, be creative, use recycled materials, to work in teams, and to foster social skills, for example.

EXPERT 10	- Two examples:
	  - A project with 6th graders where each group had to make the best vacuum cleaner in terms of looks and how it worked. The task was simple, they had a table full of trash and the robot had to clean it. They made their own designs and programmed how the Blue-Bot would clean the whole table.
	  - A project with LEGO MINDSTORMS EV3 robots, where they had to prepare a fashion show where robots were the models. The way they looked and very important.

Annex 7.2.2. – Second Delphi Questionnaire Results Summary

What is the 'A' in STEAM?	
Option	**Number of experts**
Design/Design-Thinking	7 (87,5%)
Visual Arts/Aesthetics	5 (62,5%)
Creativity	5 (62,5%)
Humanities/Liberal Arts	4 (50%)
How is the inclusion of the Arts and Humanities in STEAM done?	
Still very recent	1 (12,5%)
The theory vs. practice is still, generally, very different	1 (12,5%)
There are growing efforts to implement it in schools' STE(A)M curricula	5 (62,5%)
Mostly done by individual teachers	3 (37,5%)
Often reductive (for embellishment purposes or just for the sake of it)	1 (12,5%)

The inclusion of STEM in the Arts is easier than the Arts in STEM	1 (12,5%)
Slowly, because people fear the technological aspect	1 (12,5%)
Slowly, because some people see the value in it and others do not	1 (12,5%)
In order to prepare students for the challenges of today's world	3 (37,5%)
Not just technology based	2 (25%)
In a way that attracts a lot more girls than STEM	3 (37,5%)
How should the inclusion of the Arts and Humanities in STEAM be done?	
The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics	5 (62,5%)
The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	7 (87,5%)
STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)	5 (62,5%)
It should be a part of every school's curriculum	3 (37,5%)
Schools and teachers should have the freedom to be able to best implement it at their given context	2 (25%)
By providing teacher training and teaching material	2 (25%)
Through grassroot projects	1 (12,5%)
Through school activities/projects	3 (37,5%)
As a separate subject from the other ones	0 (0%)
Not as a separate subject, but included in the already existing ones	3 (37,5%)
From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	3 (37,5%)
Students should have prior programming knowledge so it can be better applied	0 (0%)
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities	5 (62,5%)
Use the 'A' to stimulate students to question and think about the outlook on Robotics (how	5 (62,5%)

it fits into our society, what rules should it follow, etc.)	
The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system	3 (37,5%)
The robots as tools to enhance interactivity	1 (12,5%)
The use of robots in both visual and performing arts (e.g. theatre with robots, fashion shows with robots, etc.)	3 (37,5%)
Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage	1 (12,5%)
Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum	4 (50%)
Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators	4 (50%)

Annex 7.2.3. – Third, and last, Delphi Questionnaire Results Summary

What is the 'A' in STEAM?	
Option	**Number of experts[21]**
Design/Design-Thinking	7
Visual Arts/Aesthetics	4
Creativity	4
Humanities/Liberal Arts	4
How is the inclusion of the Arts and Humanities in STEAM done?	
As something still very recent	1
The theory vs. practice is still, generally, very different	0
Mostly done by individuals	2
In a reductive way (as a way to embellish/does not contribute with something of value)	0
There are growing efforts to implement STE(A)M in schools' curricula	3
Including STEM in Arts is easier than including the Arts in STEM	0

[21] Who listed it as their number 1 priorities.

Slowly, because some people fear the technological aspect	0
Slowly, because some people see the value in it and others do not	1
In order to prepare students for the challenges of today's world and the future that awaits them	6
Not by just including technology into the regular school's curriculum	1
In a way that attracts more girls into STEM	2
How should the inclusion of the Arts and Humanities in STEAM be done?	
The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics	4
The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	5
STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.)	4
It should be a part of every school's curriculum	5
Schools and teachers should have the freedom to be able to best implement it at their given context	5
By providing teacher training and teaching material	5
Through grassroot projects	3
Through school activities/projects	4
Not as a separate subject, but included in the already existing ones	6
From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	4
What contributes to the ideal way of including the 'A' component in STEAM (K-12) education regarding Robotics?	
Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities	6
Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)	3

The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system	3
The robots as tools to enhance interactivity	2
The use of robots in both visual and performing arts (e.g. theatre with robots, fashion shows with robots, etc.)	2
Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage	2
Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum	3
Robots/Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators	5

Annex 7.2.4. – Delphi Questionnaires Results (Summary)

	1st Delphi Questionnaire				2nd Delphi Questionnaire				3rd Delphi Questionnaire[22]			
	What is the ‘A’ in STEAM?	**How is the inclusion of the Arts and Humanities in STEAM done?**	**How should the inclusion of the Arts and Humanities in STEAM be done?**	**What contributes to the ideal way of including the ‘A’ component in STEAM (K-12) education regarding Robotics?**	**What is the ‘A’ in STEAM?**	**How is the inclusion of the Arts and Humanities in STEAM done?**	**How should the inclusion of the Arts and Humanities in STEAM be done?**	**What contributes to the ideal way of including the ‘A’ component in STEAM (K-12) education regarding Robotics?**	**What is the ‘A’ in STEAM?**	**How is the inclusion of the Arts and Humanities in STEAM done?**	**How should the inclusion of the Arts and Humanities in STEAM be done?**	**What contributes to the ideal way of including the ‘A’ component in STEAM (K-12) education regarding Robotics?**
EXPERT 1	Creativity	- Through projects - It is hard because the curricula are overflowing	- Offering/ assuring students have prior knowledge in, for e.g., programming - It should be incorporated into “regular” classes	- STEAM education should go beyond Robotics - We should reflect on what one means when referring to Robotics - Instead of focusing on students learning “hard” skills, we should see	- Design/ Design-Thinking - Creativity	- There are growing efforts to implement it in schools’ STE(A)M curricula - Mostly done by individual teachers	- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - STEAM is often seen as a hard subject	- Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as	- Design/ Design-Thinking	- As something still very recent	- Schools and teachers should have the freedom to best implement it at their given context	- Use the ‘A’ to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)

[22] What they consider to be the number 1 priorities/answers

				the bigger picture - A lot of teachers are interesting in delving into STEAM activities			because it usually emphasizes these “hard” skills part, however, it is also important to highlight the “soft” skills (creativity, critical thinking, well-being, etc.)	potential technology creators				
EXPERT 2	Design-Thinking	- Adding the ‘A’ to STEM makes the concept flourish - Teachers are excited to participate in STEAM activities	- The ‘A’ should play a big role in education and life - It should be incorporated only if it makes sense	- The ‘A’ can be articulated with Robotics by prompting students to reflect on its outlook	- Design/ Design-Thinking	- There are growing efforts to implement in schools’ STE(A)M curricula - In a way that attracts a lot more girls than STEM	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - STEAM is often seen as a hard subject because it usually emphasizes these “hard” skills part, however, it is	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Use the ‘A’ to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.)	- Design/ Design-Thinking	- There are growing efforts to implement STE(A)M in school’s curricula - In order to prepare students for the challenges of today’s world and the future that awaits them - In a way that attracts more girls into STEM	- STEAM is often seen as a hard subject because it usually emphasises the “hard” skills part, however, it is also important to highlight the “soft” skills (creativity, critical thinking, well-being, etc.) - It should be part of every school’s curriculum - Not as a separate subject, but included in	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - The use of robots in both visual and performing arts (e.g., theatre with robots, fashion with robots, etc.) - Create a better relationship between the students and the community they live in by interacting with local artists, local

							also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.) - Not as a separate subject, but included in the already existing ones				the already existing ones	projects, local people and broadening their horizons by bringing to life what is taught in the curriculum - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
EXPERT 3	Arts	- Including the 'A' is the biggest challenge about STEAM after the technological aspect (because some people are afraid of it)	- STEAM should be a very important part of education because it will prepare students for the 21st century global society and economy	- By prompting students to reflect and discuss the risks and benefits of Robotics	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire

		- It should be a conversation in school and outside of it									
EXPERT 4	Arts & Humanities	- The Arts & Humanities are still not being properly included, which undervalues the component	- It should be made from the ground up	- Robotics can be articulated with Arts in order to achieve new and creative methods of expression - Robots are tools that can foster new levels of interactivity - Teachers should experiment, observe, and interpret the results of their STEAM experiments in order to adapt and enhance the process	- Design/ Design-Thinking - Visual Arts/ Aesthetics - Humanities/ Liberal Arts	- Still very recent - There are growing efforts to implement in schools' STE(A)M curricula - Mostly done by individual teachers - Slowly, because people fear the technological aspect	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - STEAM is often seen as a hard subject because it usually emphasizes	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - The use of robots both in visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.) - Create a better relationship between the students and the community they live in by	- Visual Arts/ Aesthetics -Humanities /Liberal Arts	- Mostly done by individuals - There are growing efforts to implement STE(A)M in schools' curricula - Slowly, because some people see the value in it and others do not - In order to prepare students for the challenges of today's world and the future that awaits them	- The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - Schools and teachers should have the freedom to best implement it at their given context - By providing teacher training and teaching material - From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

						these "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.) - Schools and teachers should have the freedom to be able to best implement it at their given context - By providing teacher training and teaching materials - From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators				
Arts **EXPERT 5**	- It is easier to include the STEM in Arts than the	- In an ideal world, the 'A' would be integrated in an	- The 'A' and Robotics take each	- Design/ Design-Thinking - Creativity	- The inclusion of STEM in the	- The Arts should always be included, but	- The creation of extracurricular activities, such	- Design/ Design-Thinking - Creativity	- In order to prepare students for the	- The Arts should be as important as the Sciences, Technology,	- Freedom for the schools, teachers, and students to implement

	Arts in STEM	interdisciplinary and transdisciplinary way	other to a higher level - Robotics can be a facilitator to bring STEAM into education - E.g. Artbot camp		Arts is easier than the Arts in STEM - In order to prepare students for the challenges of today's world	only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - It should be part of every school's curriculum - From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	as camps, that condense STEAM activities and complement the traditional education system - The robots as tools to enhance interactivity - The use of robots both in visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.)		challenges of today's world and the future that awaits them	Engineering, and Mathematics - The Arts should always be included, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - Through school activities/projects - Not as a separate subject, but included in the already existing ones	STEAM the way it best suits their necessities - Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system - The robots as tools to enhance interactivity - Teachers determining the robots/Robotics' artistic and humanistic learning goals in order to enhance their usage - Robots/ Robotics as a way to address more complex issues from technical, societal, and

												individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
EXPERT 6	Arts, Design-Thinking, & Humanities	- The 'A' is being introduced in STEM in order to prepare students for the future	- The integration of the 'A' in STEM happens more naturally in the business sector, and the education sector should pay attention to what is being done	- Robotics can be the perfect way of introducing challenges and problem-solving to K-12 education - Robotics can be used to perceive and reflect on the ethical side and implications of complex Robotics	- Design/ Design-Thinking - Visual Arts/ Aesthetics - Creativity - Humanities /Liberal Arts	- In order to prepare students for the challenges of today's world	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	- Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system - The use of robots both in visual and performing arts	- Design/ Design-Thinking - Visual Arts/ Aesthetics - Creativity - Humanities /Liberal Arts	- Mostly done by individuals - In order to prepare students for the challenges of today's world and the future that awaits them	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - The Arts should always be included, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system

		- STEAM is often seen as a hard subject because it usually emphasizes these “hard” skills part, however, it is also important to highlight the “soft” skills (creativity, critical thinking, well-being, etc.) - From the ground up and in order to fit the given school’s context (social, economic, cultural, etc.)	(e.g., theatre with robots, fashion shows with robots, etc.) - Teachers determining the robots/Robotics’ artistic and humanistic learning goals in order to enhance their usage - Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including	(creativity, critical thinking, well-being, etc.) - It should be part of every of every school’s curriculum - Schools and teachers should have the freedom to be able to best implement it at their given context - By providing teacher training and teaching material - Through grassroot projects - Through school activities/projects - Not as a separate subject, but included in the already existing ones - From the ground up and in order to fit the given school’s context (social, economic, cultural, etc.)	- The robots as tools to enhance interactivity - The use of robots in both visual and performing arts (e.g., theatre with robots, fashion shows with robots, etc.) - Teachers determining the robots/Robotics’ artistic and humanistic learning goals in order to enhance their usage - Create a better relationship between the students and the community they live in by interacting with local artists, local projects, and local people and broadening their horizons by bringing to life what it taught in the curriculum - Robots/ Robotics as a way to address more complex issues from technical,

								Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators				societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators
EXPERT 7	Arts & Creativity	- STEAM is still a recent concept and is still not incorporated into everyday school life - It is usually done by individual teachers - The theory vs. practice is still very different	- STEAM can truly come to fruition if teachers are given the necessary freedom to go beyond the official curriculum - Schools also need the freedom to apply STEAM in a way that best suits their environment - Through more grassroot projects specific to the school's environment	- Create a bond between students and their schools and their community (via local artists, elderly people, etc.)	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire	Did not respond to this questionnaire
EXPERT 8	Arts	- The Arts are always present	- Although the Art component is already present,	- It is difficult to say because the 'A' is	- Visual Arts/ Aesthetics	- There are growing efforts to	- The Arts should always be included, but only if it makes	- Freedom for the schools, teachers, and students to	- Design/ Design-Thinking	- In a way that attracts more girls into STEM	- The Arts should always be included, not only in an	- Freedom for the schools, teachers, and students to implement

	awareness needs to be raised so teachers better acknowledge it and incorporate it in projects and assessment	almost always present		implement in schools' STE(A)M curricula	sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way	implement STEAM the way it best suits their necessities	- Visual Arts/ Aesthetics - Creativity - Humanities /Liberal Arts	integrated way, but also in an interdisciplinary and transdisciplinary way - STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.) - It should be part of every of every school's curriculum - Schools and teachers should have the freedom to be able to best implement it at their given context - By providing teacher training and teaching material - Through grassroot projects	STEAM the way it best suits their necessities

											- Through school activities/projects - Not as a separate subject, but included in the already existing ones - From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	
EXPERT 9	Arts & Humanities	- The 'A' should be emphasised a lot because it is the foundation for STEAM	- Often, STEAM is seen as a "hard" subject because it overly focuses in the "hard" areas of the acronym, therefore, in order to best approach this pedagogy, there should be further emphasise in the 'A', the "soft" side of STEAM	- Through granting freedom to design, be creative, use recycled materials, to work in teams, and to foster social skills, for example	- Design/ Design-Thinking - Visual Arts/ Aesthetics - Creativity - Humanities /Liberal Arts	- Mostly done by individual teachers - In order to prepare students for the challenges of today's world - Not just technology based - In a way that attracts a lot more girls than STEM	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - Create a better relationship between the students and the community they live in by	- Design/ Design-Thinking - Visual Arts/ Aesthetics - Humanities /Liberal Arts	- In order to prepare students for the challenges of today's world and the future that awaits them - Not by just including technology into the regular school's curriculum	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics - The Arts should always be included, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - STEAM is often seen as a hard subject because it usually emphasises the "hard" skills part, however, it is also important	- Freedom for the schools, teachers, and students to implement STEAM the way it best suits their necessities - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators

							transdisciplinary way - STEAM is often seen as a hard subject because it usually emphasizes these "hard" skills part, however, it is also important to highlight the "soft" skills (creativity, critical thinking, well-being, etc.) - It should be part of every school's curriculum - Not as a separate subject, but included in the already existing ones	interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is taught in the curriculum - Robots/ Robotics as a way to address more complex issues from technical, societal, and individual points of view, including Ethics, which will provide a better understanding for the complex role that students have in our society and their role in the future as potential technology creators			to highlight the "soft" skills (creativity, critical thinking, well-being, etc.) - It should be part of every of every school's curriculum - Schools and teachers should have the freedom to be able to best implement it at their given context - By providing teacher training and teaching material - Not as a separate subject, but included in the already existing ones - From the ground up and in order to fit the given school's context (social, economic, cultural, etc.)	
EXPERT 10	Arts & Design-Thinking	- Now it goes beyond the technology, and it is easier to	- In his environment, the 'A' is as important as the rest of the areas in STEAM, and	- Through design projects, where the 'A' focus more on the	- Design/ Design-Thinking - Visual Arts/ Aesthetics	- There are growing efforts to implement in	The Arts should be as important as the Sciences, Technology,	- Freedom for the schools, teachers, and students to implement STEAM the	- Design/ Design-Thinking - Creativity	- There are growing efforts to implement STE(A)M in	- The Arts should be as important as the Sciences, Technology, Engineering, and Mathematics	- The creation of extracurricular activities, such as camps, that condense STEAM activities

	"sell" to stakeholders	that reflects in his teachers' belief and excitement about STEAM projects	aesthetic facet	- Creativity - Humanities /Liberal Arts	schools' STE(A)M curricula - Slowly, because people fear the technological aspect - Not just technology based - In a way that attracts a lot more girls than STEM	Engineering, and Mathematics - The Arts should always be included, but only if it makes sense, not only in an integrated way, but also in an interdisciplinary and transdisciplinary way - It should be part of every school's curriculum - By providing teacher training and teaching materials - Through grassroot projects - Not as a separate subject, but included in the already existing ones	way it best suits their necessities - Use the 'A' to stimulate students to question and think about the outlook on Robotics (how it fits into our society, what rules should it follow, etc.) - The creation of extracurricular activities, such as camps, that condense STEAM activities and complement the traditional education system - Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people, and broadening their horizons by bringing to life what is		school's curricula - In order to prepare students for the challenges of today's world and the future that awaits them	- It should be part of every school's curriculum - By providing teacher training and teaching material - Through grassroot projects - Through school activities/projects - Not as a separate subject, but included in the already existing ones	and complement the traditional education system - Create a better relationship between the students and the community they live in by interacting with local artists, local projects, local people and broadening their horizons by bringing to life what is taught in the curriculum

	taught in the curriculum	

7.3. Critical Incident Technique's interview script

The following script was the basis for the Critical Incident Technique semi-structured interviews, that were conducted via Zoom with each one of the six selected experts.

Questions (please answer based on your personal/professional experience)

1. First of all, how does your work relate with STEAM or Robotics and its implementation in the European context?
2. What do you consider to be the 'A' in STEAM?
3. What do you believe is the role of Robotics not only now but in the future? Do you have a more positive, negative, or neutral perspective?
4. Do you think that STEAM in a school curriculum should be an extra class, or do you think it should be incorporated into the traditional ones?
5. What do you consider to be the value and the contribution of the Arts and Humanities in education?
6. Do you believe that the current general education system is obsolete? (Public schools mostly)
7. Do you believe the 'A' in STEAM should have the same weight as the other areas?
8. What do you think is the gap between how Arts and Humanities are **being** included in STEAM and how they **should be** included?
9. What do you think is the biggest obstacle to STEAM or educational robotics implementation?
10. Based on your experience and your knowledge, what do you consider to be the ideal way of including the 'A' in STEAM (K-12) education regarding Robotics?

7.4. Critical Incident Technique data collection results (summary)

The following table synthesizes the answers to the questions posed during the Critical Incident Technique's interviews. In bold are the questions presented to the experts and below their synthesised answers often categorised to make the reading easier.

CIT data synthesis overview

1. Background of the experts and how their work relates to the implementation of STEAM and/or Robotics in the European context[23]

Background	Work
• Education • Computer Science • History • IT Engineering • Philosophy • Communications Science • Electrical Engineering	• STEAM teacher • Microsoft recognised teachers • Consultant in (educational) Robotics • STEAM coordinator • Vice-president of an educational Robotics institution • Principal of a school with a STEAM track • Teacher of Arts & Crafts, Design-Thinking, and Computer Science

2. What the 'A' stands for

- Creativity
- Arts & Humanities
  - Reflection
  - Ethics
  - Culture
  - Etiquette
- Design-Thinking
- Arts
  - In a visual sense
  - Beauty and aesthetic

3. Role of Robotics in the present and future

Positive perspective	Neutral perspective	Negative perspective
• It is going to be increasingly useful and important • It will have a protagonist role	• It will depend on the next generation of roboticists	• It will be similar to the negative stories portrayed in Science Fiction

4. Should STEAM be an extra class or part of the curriculum of "regular" classes

Extra class	Part of "regular" classes	Other
• Because topics related to STEAM deserve a fixed spot in the curriculum • There are a lot of extracurricular activities and projects that can be done	• But, at this time, it is still a very utopic concept • It should be incorporated where it makes sense	• It is still a "difficult" question to tackle, because there is no clear answer • It can stay as an extra class until there is a better and easier way to integrate it into the regular curriculum

5. Value and contribution of the Arts and Humanities

- They cultivate responsibility
  - To dream, to find solutions

[23] One expert can have more than one background and more than one job role.

- To understand and minimize human bias
- They promote self-steering, self-regulation, self-reflection, self-knowledge, and critical thinking
- They encourage imagination and passion
- They reinforce the talent inherent to students
- They foster creativity
- They instil Design-Thinking
- They help understand our present moment, understand ourselves, and why things are the way they are
  - They carry our culture and values

6. Status of the current educational system (in the experts' country)

Obsolete	Mixed	Advanced/Updated
• Outdated contents • Lack of flexibility (curriculum, teachers, students, etc.)	• The school system is quite complex • The system needs work, but it is not totally faulty • It is slowly improving • Due to historical factors, the modernisation is rather slow, but it is happening	• The school curriculum has been recently modernised and there has been a lot of progress • However, some things still need to change (curriculum flexibility, teacher training, etc.)

7. Should the 'A' have the same weight as the other areas of STEM

Yes	Other
• Because creativity is crucial • Because Design-Thinking is quite important • By including it in the context and the essence of the contents • But the most important part is to be able to solve complex problems • But only if it makes sense	• It is something hard to do in some contexts, due to the strictness of the curriculum

8. How the Arts and Humanities are being included in STEAM vs how they should be included

How they are	How they should be
• Most schools do not include the 'A' • It is mostly included as a way to embellish (reductive inclusion)	• Included since the very beginning and not just an embellishment factor • There should be more projects and activities that allow the collaboration between Design-Thinking and real problem-solving • The Arts should be seen in a broader sense, including the Arts and Humanities, and by including them in the context and essence of a given project • The curricula should be adjusted to accommodate STEAM

- Teachers need to be given the necessary freedom to go into a wider aspect of their discipline

9. Biggest obstacles to STEAM and Robotics implementation in education

- Official curriculum
  - The disconnection between the materials being taught in class and the world outside
  - Which makes the collaboration between teachers and subjects a lot harder
  - Lacks flexibility and adaptability
- Teacher training
- Money/Cost of technology/Lack of funding
- No STEAM in schools' curriculum
- Lack of teaching materials and guidelines
- Designing a curriculum that will accompany students for several years of their school path
- The goal being grades instead of knowledge acquisition

10. Ideal ways of including the 'A' in STEAM (K-12) education concerning Robotics

- Through a project where the students have to go through the whole process of creating something
  - Brainstorming, understanding the target audience, their taste, collecting the necessary data, prototyping, design-thinking, etc.
- By focusing on the 'A' in STEAM
  - But integrating it only in a way that makes sense (not in a reductive way), in the context and essence of the project
- By understanding that sometimes we will not be able to include all the letters that are part of STEAM in every single project
- By supporting and investing in the teachers
- By funding these type of activities
- By modernising the curriculum
- By introducing Robotics and STEAM education in early childhood as a part of Fine Arts
- By creating competitions or initiatives outside of the school's curriculum
- By creating competence levels (like foreign language classes) so the adjustment is easier and can be adapted to the students' needs and abilities

7.5. List of readings

List of the readings done over the course of the dissertation's process

Type	Title	Author(s)	Year	Theme
Journal article	*Are robots becoming unpopular? Changes in attitudes towards autonomous robotic systems in Europe*	Timo Gnambs & Markus Appel	2019	Robotics
Report	*Arts and Humanities Research and Innovation*	Hasan Bakhshi, Philippe Schneider,	2008	Arts & Humanities

		& Christopher Walker		STEAM education
Journal article	*Case studies on the transfer of knowledge within the interdisciplinary STEAM curricula construct*	Laura Rachel Fattal	2019	STEAM education
Journal article	*Creating meaning. The importance of Arts, Humanities and Culture for critical thinking development*	Daniela Dumitru	2019	Arts & Humanities STEAM Education
Book chapter	*Dancing, Drawing, and Dramatic Robots: Integrating Robotics and the Arts to Teach Foundational STEAM Concepts to Young Children*	Amanda Sullivan, Amanda Strawhacker, & Marina Umaschi Bers	2017	STEAM Education Robotics
Book chapter	*Development and Application of the STEAM Education Program Based on the Soccer Robot for Elementary Students*	Ma-byong Yoon, & Je-eun Baek	2018	STEAM Education Robotics
Journal article	*Education biases perception of social robots*	R. Szczepanowski, E. Cichon, K. Arent, J. Sobecki, P. Styrkowiec, M. Florkowski, & M. Gakis	2020	Robotics
Journal article	*Educational Research: The Importance of the Humanities*	Richard Smith	2015	Arts & Humanities
Journal article	*Educational robotics: Open questions and new challenges.*	Dimitris Alimisis	2013	STEAM Education Robotics
Book	*Emerging Technologies for STEAM Education: Full STEAM Ahead*	J. Michael Spector, M. J. Bishop, Dirk Ifenthaler (ed.)	2015	STEAM Education
Journal article	*Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators*	Danielle Herro & Cassie Quigley	2016	STEAM Education
Journal article	*Faster pedagogical framework for steam*	Robertas Damaševičius, Rytis	2018	STEAM Education Robotics

	education based on educational robotics	Maskeliūnas, & Tomas Blažauskas		
Journal article	*Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review.*	Miguel Á. Conde, Francisco J. Rodríguez-Sedano, Camino Fernández-Llamas, José Gonçalves, José Lima, & Francisco J. García-Peñalvo,	2021	STEAM Education Robotics
Journal article	*From STEM to STEAM: How to Monitor Creativity*	Cathérine Conradty & Franz X. Bogner	2018	STEAM Education
Journal article	*From STEM to STEAM: Reframing What it Means to Learn*	Nicole M. Radziwill, Morgan C. Benton, & Cassidy Moellers	2015	STEAM Education
Journal article	*Full STEAM Ahead – a Collaborative Colloquium*	Hilary Dito	2013	STEAM Education
Journal article	*Full STEAM Ahead: The Benefits of Integrating Arts Into STEM*	Michelle H. Land	2013	STEAM Education
Book	*Human-Robot Interaction: An Introduction*	Christoph Bartneck, Tony Belpaeme, Friederike Eyssel, Takayuki Kanda, Merel Keijsers, Selma Sabanovic	2020	Robotics
Book	*Humans Need Not Apply*	Jerry Kaplan	2015	Robotics
Journal article	*Humans, robots and values*	Paul Cockshott & Karen Renaud	2016	Arts & Humanities Robotics
Book	*I, Robot*	Isaac Asimov	1950	Arts & Humanities Robotics
Web article	*IFR presents World Robotics Report 2020*	IFR	2020	Robotics
Journal article	*Implementation of STEAM Education to Improve Mastery Concept*	W. Liliawati, H. Rusnayati, Purwanto, & G. Aristantia	2017	STEAM Education
Journal article	*Internationalizing the Curriculum for STEAM (STEM + Arts and Humanities): From Intercultural Competence to Cultural Humility*	Armida de la Garza	2019	STEAM Education

Journal article	*Make Way for the Robots! Human- and Machine-Centricity in Constituting a European Public–Private Partnership*	Kjetil Rommetveit, Niels van Dijk, & Kristrún Gunnarsdóttir	2020	Robotics
Journal article	*Meaningful Makers: Stuff, Sharing, and Connection in STEAM Curriculum*	Ryan M. Patton & Aaron D. Knochel	2017	STEAM Education
Book	*New Laws of Robotics: Defending Human Expertise in the Age of AI*	Frank Pasquale	2020	Arts & Humanities Robotics
Web article	*Post-COVID-19 Economy: "Robots Create Jobs"*	IFR	2020	Robotics
Book	*Promoting Language and STEAM as Human Rights in Education: Science, Technology, Engineering, Arts and Mathematics*	Zehlia Babaci-Wilhite (ed.)	2019	STEAM Education
Journal article	*Rethinking STEM Education: An Interdisciplinary STEAM Curriculum*	Margaret E. Madden, Marsha Baxter, Heather Beauchamp, Kimberly Bouchard, Derek Habermas, Mark Huff, Brian Ladd, Jill Pearon, & Gordon Plague	2013	STEAM Education
Journal article	*Robo-Ethics A Survey of developments in the field and their implications for social effects*	P. Kopacek	2019	Arts & Humanities Robotics
Journal article	*Roboethics in education and society*	Michael A. Peters	2020	Arts & Humanities Robotics
Journal article	*Roboethics: a Bottom-Up Interdisciplinary Discourse in the Field of Applied Ethics in Robotics*	Gianmarco Veruggio & Fiorella Operto	2006	Arts & Humanities Robotics
Book chapter	*Roboethics: Social and Ethical Implications*	Gianmarco Veruggio, Fiorella Operto, & George Bekey	2016	Arts & Humanities Robotics
Book chapter	*Roboethics: Social and Ethical Implications of Robotics*	Gianmarco Veruggio & Fiorella Operto	2008	Arts & Humanities Robotics
Web article	*Robot Race: The World´s Top 10 automated countries*	IFR	2021	Robotics

Book chapter	*Robotics Education Done Right: Robotics Expansion, A STEAM Based Curricula*	Anthony J. Nunez	2016	STEAM Education Robotics
Journal article	*Robotics Nudges: The Ethics of Engineering a More Socially Just Human Being*	Jason Borenstein & Ron Arkin	2016	Arts & Humanities Robotics
Book chapter	*STEAM and Educational Robotics: Interdisciplinary Approaches to Robotics in Early Childhood and Primary Education*	Lorenzo Manera	2020	STEAM Education Robotics
Book	*STEAM Education: Theory and Practice*	Myint Swe Khine & Shaljan Areepattamannil	2019	STEAM Education
Journal article	*STEAM in practice and research: An integrative literature review*	Elain Perignat & Jen Katz-Buonincontro	2018	STEAM Education
Journal article	*STEAM: The wave of the future embedded in ideals of the past*	Sheena Ghanbari	2014	STEAM Education
Journal article	*STEM + Art = STEAM*	John Maeda	2013	STEAM Education
Journal article	*STEM: Moving the liberal arts education into the 21st century*	Scott Bevins	2011	Arts & Humanities STEAM Education
Book	*Superintelligence: Paths, Dangers, Strategies*	Nick Bostrom	2014	Robotics
Book	*Surrogate Humanity: Race, Robots, and the Politics of Technological Futures*	Neda Atanasoski & Kalindi Vora	2019	Robotics
Journal article	*The Emergence of the Creativity in STEM: Fostering an Alternative Approach for Science, Technology, Engineering, and Mathematics Instruction Through the Use of the Arts*	Michael Marmon	2019	STEAM Education
Book	*The Hedgehog, the Fox, and the Magister's Pox: Mending the Gap between Science and the Humanities*	Stephen Jay Gould	2011	Arts & Humanities STEAM Education Robotics

Book	*The Question Concerning Technology and Other Essays*	The Question Concerning Technology and Other Essays	1977	Robotics
Book	*The STEAM Revolution: Transdisciplinary Approaches to Science, Technology, Engineering, Arts, Humanities and Mathematics*	Armida de la Garza & Charles Travis (ed.)	2019	Arts & Humanities STEAM Education
Book	*The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century*	Jerome Kagan	2009	Ars & Humanities STEAM Education
Journal article	*The Utility of the Arts and Humanities*	Michael Bèrubè	2003	Arts & Humanities STEAM Education
Book	*The World As I See It*	Albert Einstein	2006	Arts & Humanities
Journal article	*Theater meets robot – toward inclusive STEAM Education*	Calkin Suero Montero & Ilkka Jormanainen	2016	STEAM Education Robotics
Web article	*Top 5 Robot Trends 2021*	IFR	2021	Robotics
Journal article	*Understanding the Role of Arts and Humanities in Social Robotics Design: An Experiment for STEAM Enrichment Program in Thailand*	Potiwat Ngamkajornwiwat, Pat Pataranutaporn, Werasak Surareungchai, Bank Ngamarunchot, & Tara Suwinyattichaiporn	2017	Arts & Humanities STEAM Education Robotics
Journal article	*What is it about humanity that we can't give away to intelligent machines? A European perspective.*	Crispin Coombs, Patrick Stacey, Peter Kawalek, Boyka Simeonova, Joerg Becker, Katrin Bergener, João Álvaro Carvalho, Marcelo Fantinato, Niels F. Garmann-Johnsen, Christian Grimme, Armin Stein, & Heike Trautmann	2021	Arts & Humanities Robotics

Journal article	*Why is a STEAM curriculum perspective crucial to the 21st century?*	Peter Charles Taylor	2016	STEAM Education