Macro-dissemination of *maker culture*: fostering 21st century competencies through an *Ideaton*

Macro-diseminación de la *cultura maker*: promoviendo competencias del siglo XXI a través de un *Ideatón*

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Abstract

With the aim of fostering innovation culture and entrepreneurship through directed ideation, a co-techno-creative competition was held for 1,000 senior high school students, as part of the 2018 Epicentro Innovation Festival in Jalisco, Mexico. The competition objectives were aligned with the United Nations' Sustainable Development Goals, whose methodology was based on evoking practical and innovative solutions to the local problems of the eight strategic sectors of the state. The prototyping activity was characterized by the inclusion of programmable microcontrollers, sensors, and actuators, which fosters the development of 21st century competencies such as creativity, collaboration, critical thinking, computational thinking, and problem solving. The participant follow-up, using a digital platform, was set for a year. The logistical scheme developed by the Ministry of Innovation, Science and Technology (SICyT) in collaboration with the Universidad de Guadalajara, and the research design jointly proposed by three universities, in Mexico, Canada, and France, are also presented.

Keywords: Maker education; 21st century competencies; collaborative learning; creativity; problem solving; open innovation.

Resumen

Con el objetivo de promover la cultura de innovación y emprendimiento a través de la ideación dirigida, se llevó a cabo una competición co-tecno-creativa para 1000 estudiantes de bachillerato, durante el Festival de Innovación Epicentro 2018 en Jalisco, México. Los objetivos de la competición estuvieron alineados a los Objetivos de Desarrollo Sostenible de la Organización de las Naciones Unidas, cuya metodología se centró en evocar soluciones prácticas e innovadoras a problemáticas locales de ocho sectores estratégicos del estado. La

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actividad de prototipado se caracterizó por la inclusión de microcontroladores programables, sensores y motores, que permiten el desarrollo de competencias del siglo XXI tales como creatividad, colaboración, pensamiento crítico, pensamiento computacional y resolución de problemas. El seguimiento a los participantes se estableció a un año utilizando una plataforma digital. Se presentan el esquema logístico realizado en colaboración entre la Secretaría de Innovación, Ciencia y Tecnología (SICyT) y la Universidad de Guadalajara, así como el protocolo de investigación planteado entre tres universidades de México, Canadá y Francia.

Palabras clave: Educación maker, competencias del siglo 21; aprendizaje colaborativo; creatividad; resolución de problemas; innovación abierta.

1. Introduction

1.1 The Open Innovation 2.0 paradigm (OI2)

The transition from a knowledge economy to an applied creative economy requires an ecosystem with mechanisms focused on entrepreneurs to support the realization of innovative ideas (Florida, 2014). In the case of Mexico, technological projects for innovation have traditionally been orchestrated by the *Government + Industry + Academy/Research* triad, excluding users in the process. Users are usually only perceived as recipients of innovation. This disarticulation of the relevant helices typically affects users as potential entrepreneurs, compromising the vision of their ideas or projects, with the result that, even with financial support, they generate prototypes of limited originality and relevance, which never achieve positioning in the market, and therefore are not able to cross the so-called Valley of Death (Markham et al., 2010), a journey in which ideas and prototypes manage to survive or otherwise 'die'.

The Open Innovation 2.0 paradigm (OI2) has enabled us to rethink the place of citizens in this process, adding the "Users/Society" helix to the triad, generating the quadruple helix of the O12 innovation model (Carayannis & Campbell, 2009). The OI2 not only enables active engagement of the efforts of the four helices, namely *Government + Industry + Academy/Research + Users/Society*, but prioritizes users' participation as architects of their own solutions. Likewise, it promotes the collaborative use of technologies for co-techno-creation, through the democratization of low-cost devices, friendly design, and the open dissemination of information over the Internet. This rethinking is observable in the emergence of a culture of doing, or *maker culture*, a resurgence of the Do-it-yourself (DIY) movement in non-formal learning spaces, such as *makerspaces*, Fab Labs, open creative spaces, and Hackerspaces; but is also increasingly seen in formal education institutions (Domingo-Coscollola et al., 2018) and parapublic organizations such as libraries (Curry, 2017), museums (Sheridan et al., 2014), and community centers (Sheridan & Konopasky, 2016). (see Figure 1).

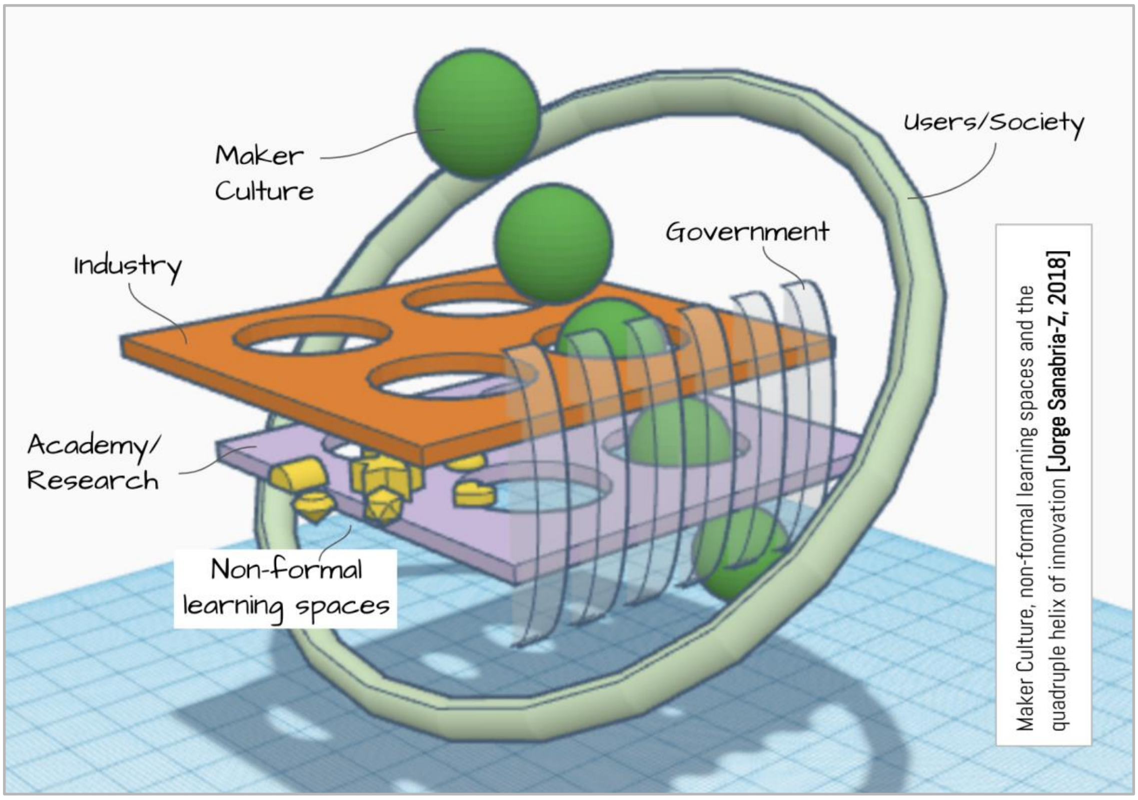

Figure 1. *Maker culture, non-formal learning spaces, and the quadruple helix of innovation.* (Source: Sanabria-Z, J., 2018)

1.2 Maker culture in education

Since 2012, *maker culture*, also understood as a movement, has gained great popularity in education because of its potential to bring real-world problems and challenges to the classroom, and prepare students for the demands of society and the intended job market (Dougherty, 2012). *Maker culture* permeates the four helices of innovation represented in Figure 1, and is particularly emphasized in the *Academia/Research* helix, based on the concept of *maker education*, which follows a constructivist approach to learning (Fleming, 2015; Papert & Harel, 1991). Ideally, in *maker education*, the participants are agents who create an artifact (prototype, technological device, etc.) through which they learn, using traditional (e.g., manual) and digital tools, along with disruptive technologies, such as 3D printing, as well as traditional materials. Instead of high-stakes individualistic projects such as those traditionally favored in schools, *makers* engage in self-directed experiential learning through risk-tolerant persistent problem solving in interdependent informal communities tackling complex socially-relevant problems (Davidson & Price, 2017). Learning through making is interdisciplinary and intergenerational, and oscillates between formal and informal contexts, which can transform educational practices, foster progressive pedagogy, and make learning more relevant (Cucinelli et al., 2018; Halverson & Sheridan, 2014).

In *maker education*, the designer of educational contexts, projects, and activities offers resources for the development of so-called 21st century competencies, which enables participants to situate themselves in a context of problem solving through the use of technology (Romero & Gebera, 2012; Sanabria & Romero, 2018; Sanabria-Z & Romero, 2019). In addition, through *maker*-type techno-creative activities, the low-to-high-definition prototyping process is promoted, thus boosting the quality and relevance of new ideas of products and services. It has been shown that having a robust infrastructure for creating prototypes helps entrepreneurs overcome the aforementioned Valley of Death (Klitsie et al., 2018). Hence, efforts to promote the early conception of ideas and competencies that could be developed using cutting-edge emergent and disruptive technologies may contribute to the generation and improvement of innovative products.

Maker culture is an expression of the willingness to access and develop low-cost solutions in a context of citizen-based innovation. From this perspective, *maker* activities often involve small DIY projects using compact and affordable open-source computers, electronic items, and recycled materials, to promote sustainability, equity, social innovation, the democratization of innovation, and the construction of communities (Andersson, 2015). Instead of focusing on decontextualized learning objectives or points-based individual learning activities, as is usual in schools, educational *maker* projects develop team activities based on self-directed experiential learning. This type of learning can foster problem solving, tolerance to ambiguity, and risk tolerance in contexts of complex and socially relevant problems. Resources for *maker education* are proliferating in schools (Burker, 2015), libraries (Haug, 2014), and community centers (Sheridan et al., 2014) in several countries.

Without research that investigates not only how to develop technological know-how, but also thinking processes grounded in research evidence and traces of reflection, learning, and iterations, *makers* risk becoming “techno-fetishists” who utilize electronic equipment and participate in technical competitions instead of focusing on the social innovation that can be conveyed by *maker* activities (Hertz, 2012); and *makerspaces* run the risk of becoming mere rental spaces or showcases of *makers'* works, instead of promoting education (Peppler et al., 2016) in collaborative communities that engage in shared activities (Fox, 2014).

With this in mind, Davidson et al. (2017) compiled various forms of data involving participants who took part in formal and non-formal activities led by *makers*, such as *maker* workshops, *maker* jams, hackathons and *maker* challenges. The authors identified various characteristic attitudes such as taking initiative, learning playfully, authentic adaptation, and persistence; and competencies including collaboration, co-design, and joint planning. In addition, to be successful in *maker* activities, students must develop the capacity to tolerate error, deal with uncertainty, and solve problems at different levels of difficulty and complexity (Davidson & Price, 2017). The ability to work effectively at different levels of complexity is a critical requirement in a world increasingly defined by the integration of technologies (generally referred to under the rubric of artificial intelligence), but also in specific and burgeoning fields such as robotization (Romero, 2017) and comprehensive design.

1.3 Bridging the gap from maker education to the development of 21st century competencies

Most teachers are ill-equipped to teach advanced technological competencies such as creative programming, despite the need for learners to be able to acquire critical computational citizenship and successfully enter a job market undergoing rapid and unpredictable changes. Like never before, students need to learn to persevere and persist (Sheridan et al., 2014), solve ill-defined problems, and work in collaborative groups (Cucinelli et al., 2018; Davidson et al., 2017; Davidson & Price, 2017). In schools, decisions to integrate the *maker movement* often involve the purchase of commercial kits and class sets of STEAM resources which do not offer learning activities that reflect the true potential of the *maker movement* or foster the development of 21st century skills.

This developmental need comes almost 40 years after Papert (1980) discussed how computers can reverse the teaching-learning relationship, enabling children to control the computers, teach the computers how to think, and theorize in a manner suggestive of epistemologists who build their own intellectual structures akin to Piaget's work on genetic epistemology. At the time, Papert's ideas were received with great skepticism; it was not at all clear why it was important to teach children how to program robots and computers. This issue, however, is no longer a matter for debate, and student-centered pedagogies are highly desired. In *maker* classrooms, we often find children utilizing kits, ranging from MaKey MaKey invention kits and LittleBits to Lego Mindstorms (Peppler et al., 2016), which become metaphors and mental models of what is possible in this so-called Fourth Industrial Revolution. These kits typify the desire for *maker* pedagogy in the classroom. However, difficulties may arise with regard to their implementation (Blikstein & Worsley, 2016); for example, it may be difficult to scale up their adoption, as they are not accessible to all budgets. We also know very little about what learners understand through the pedagogical use of the kits, and how the takeaways transfer to other contexts and ultimately to preparation for the job market.

From an educational standpoint, what youth learn through *maker culture* is central to understanding both what it means to be a 21st century citizen and their value as workers and transnational citizens in the era of the Internet of things (IoT) and Industry 4.0. However, merely using STEAM kits or assembling *maker* kits is far from sufficient as preparation for the future. It is necessary to generate the right conditions to contextualize mentors who guide the learning process in *maker* education situations, by familiarizing them with relevant problems, sharing *maker* methodologies, and encouraging them to empathize with participants in their course or workshop activities in order to achieve meaningful projects.

As an initiative to address the need for mentors in formal and non-formal environments to grasp a *maker education* approach, a first Maker Fundamentals course-workshop was launched by the Committee of Culture and Education in Maker Ecosystems, part of the Mexican Thematic Network for the Development and Incorporation of Educational Technology (Red LaTE), in collaboration with the Universidad de Guadalajara (UdeG). This introduction to the use of digital fabrication technologies and *maker* educational methodologies aimed to sensitize teachers and mentors of basic, middle, and higher educational levels, regarding the usefulness of these tools for the development of 21st century competencies in their students. The 5-day experience was based on the Gradual Immersion Method (Sanabria, 2015), a pedagogical approach driven by three modules for intuitive learning: familiarization, co-creation, and exhibition (UDGVirtual, 2018) (see Figure 2).

Figure 2. *First "Maker Fundamentals" teacher training in summer 2018 organized by Red LaTE and the Universidad de Guadalajara.* (Source: Alatorre, K., 2018)

To continue bridging this gap in the learning process, between traditional and *maker* education, Davidson et al. (2017) studied which fundamental knowledge or skills might be necessary to propel learners into more socially relevant *maker* activities. The team worked from the premise that once certain fundamental elements are mastered, learners can use these as a form of currency to solve problems that require interacting with hardware parts, coding, assembling, and creating new solutions and new affordances of technology. They revealed that once having acquired some knowledge of basic electronics, microcontrollers, robotics, and prototyping, and basic know-how in the manipulation and use of related tools, including their safety aspects, teachers and students are able to engage in more creative activities because they have built creative self-confidence (see Figure 3).

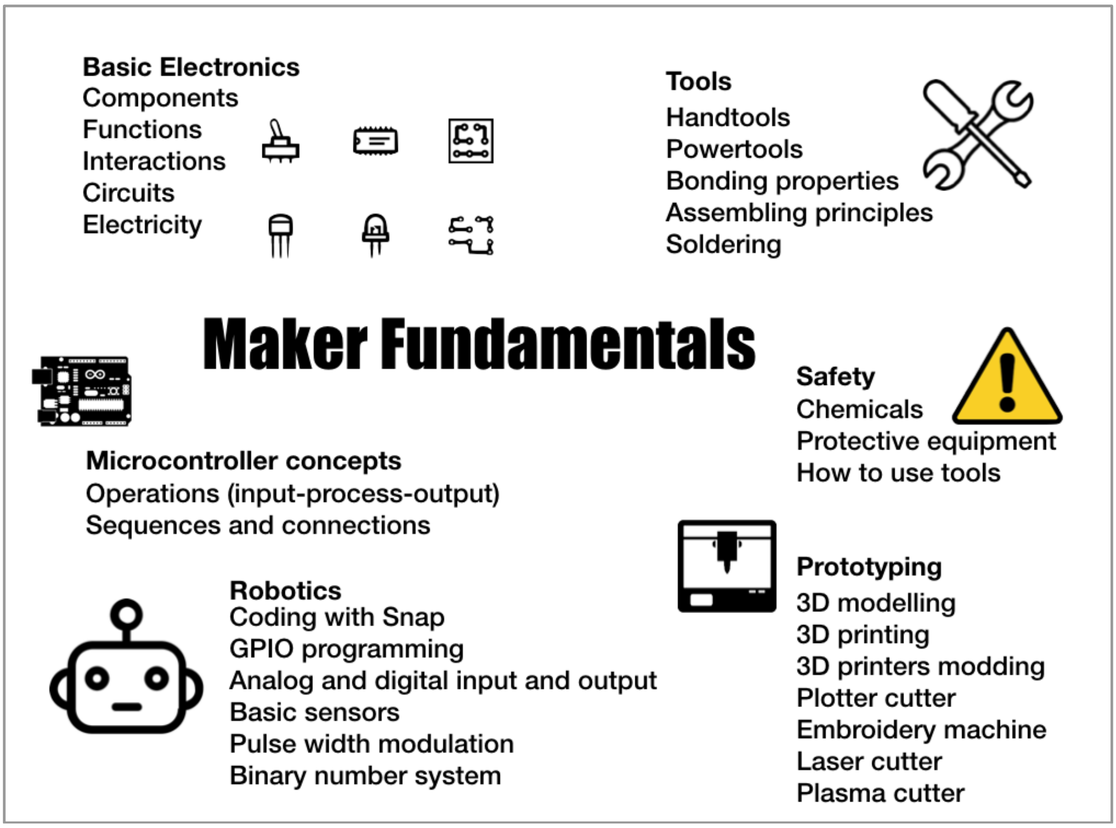

Figure 3. *Maker fundamentals necessary to engage in intermediate maker education activities.* (Source: Davidson et al., 2017)

1.4 21st century Competencies

Given this context of *maker culture* proliferation, we must focus not only on knowledge, but also on the development of competencies that enable individuals to adapt to different social and professional contexts. *Maker culture* presents an effective means for the development of 21st century competencies, which respond to contemporary educational and socio-professional challenges. There is often significant complexity in the prototype development process in which a user is situated, which implies a large number of problem-solving situations that lead to critical and creative reflection on the uses of different analogue and digital technologies (Romero & Gebera, 2012; Sanabria & Romero, 2018), and traditional as well as futuristic materials such as bio-materials (Davidson & Naffi, 2019).

The framework of key competencies for the 21st century on which this article is based comprises problem solving, critical thinking, creativity, computational thinking, and collaboration. Four of these five competencies are part of the Quebec training program (MEES, 2010). The competence in computational thinking is recent, and has been integrated into various training programs in different countries of the world (see Figure 4).

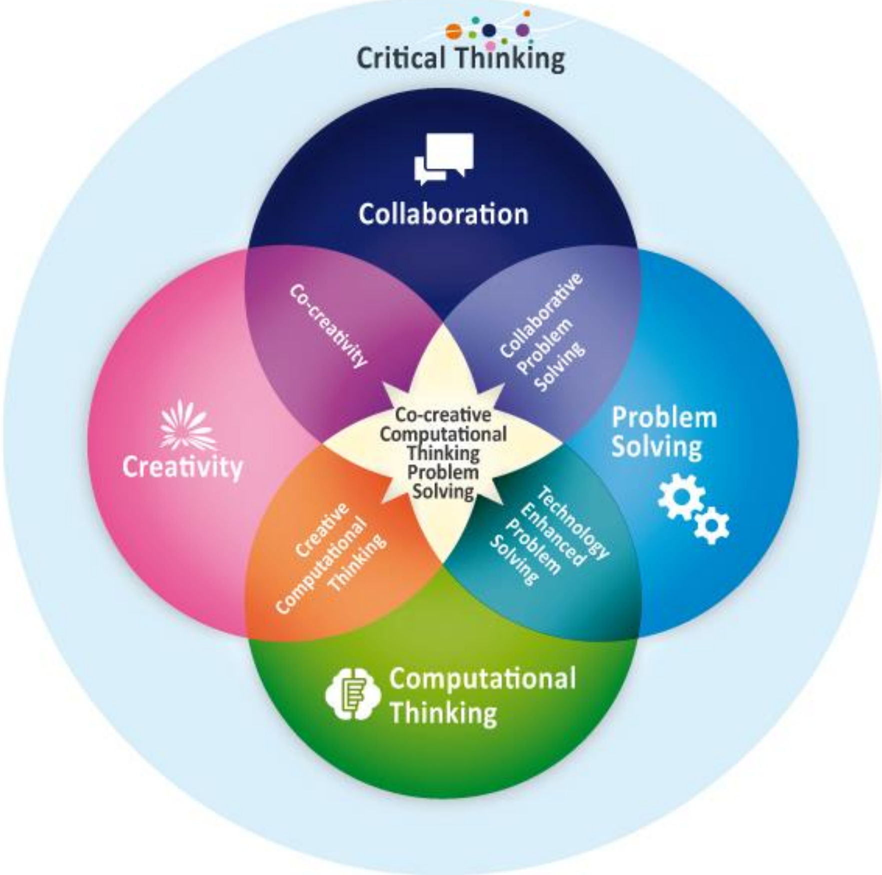

Figure 4. #CoCreaTIC's framework of 21st century five competences. (Source: Romero & Vallerand, 2016).

The competence in critical thinking (represented as the background in the figure above) subsumes the other four competencies, because it is necessary to analyze the situation of a problem before defining the type of solution and creating the prototype. Computational thinking is considered to be a set of strategies by which a problem is solved, with or without technology, using concepts and computer processes. Cuny et al. (2010) define computational thinking as the "thought processes involved in the formulation of problems and the search for their solutions, so that the solutions are represented in such a way that they can be effectively executed by an agent that processes the information".

The relationship between the competencies in computational thinking and problem solving was implicit from the beginning of the definition of the former by Wing (2006, 2008). The act of creating a new solution through processes that are not known in advance relates both competencies to creativity. Finally, in predominant contexts, most of the activities are performed collaboratively in more or less informal groups. The ability to work as a team, or in collaboration, is therefore essential as a competence in these contexts, and may be transposed into macro scenarios such as those that operate in work situations.

1.5 The *Ideaton* techno-creative program as a research context

The heuristic context for this article was the *Ideaton-2018* program for youth, part of the Epicentro Innovation Festival, in Jalisco, Mexico. The *Ideaton-2018* was the second edition of the *Ideaton* program that was first held in 2017, an initiative of the Ministry of Innovation, Science and Technology (SICyT), enhanced in collaboration with UdeG through the latter's Virtual University System.

1.5.1 The challenges facing Jalisco and the work of its Ministry of Innovation

The second decade of this century has been notable for the promotion of entrepreneurship in Mexico. Among other initiatives, the establishment of seed capital for investment in new high-tech companies was achieved with the support of the state development bank; the National Entrepreneur Institute (INADEM) was launched, in charge of documenting and supporting the needs of small and medium enterprises; the collaborative initiative of the governments of the United States and Mexico was consolidated by the development of a Council for Entrepreneurship and Innovation (MUSEIC), focusing on improving regional capacity through the strengthening of high impact ecosystems; as well as the constant increase of funds for research.

Some of the primary conditions for the proper development of an innovation ecosystem were presented in 2013 during the High Level Innovation Forum for Mexican legislators, organized by the Mexico Institute, part of the Woodrow Wilson International Center for Scholars; an event that focused on increasing understanding of the benefits and challenges of innovation. These conditions can be summarized as: generating robust financing for research and development; creating paths to available financing; establishing alliances between the Academy/Research and Industry helices; encouraging the constant formation of business networks; considering a vision and praxis for international collaborations; and of particular interest, fostering a culture of innovation (Wood et al., 2014).

The state of Jalisco was also vigorous in supporting the initiatives of this entrepreneurial decade, launching its own Ministry of Innovation, Science and Technology (SICyT) in 2013. Since its inception, numerous mechanisms and strategies have been implemented to develop the state economy along entrepreneurial lines. In addition to traditional initiatives such as investment in innovation, strengthening the financial sector, and labor or educational reform, the ministry was mandated to foster a culture of innovation and entrepreneurship, in keeping with the expert vision of the presenters of the High Level Innovation Forum.

1.5.2 The Epicentro Innovation Festival

The Epicentro Innovation Festival emerged in 2014 as an annual initiative of the Ministry of Innovation, Science and Technology of the State of Jalisco, with the double objective of developing the local economy and generating well-being in the region, and has grown to become one of the largest events of its kind in the country, drawing around 50,000 participants each year. "Epicentro aims to strengthen the high impact entrepreneurship ecosystem of Jalisco through the promotion of a culture of innovation and facilitating access to knowledge, skills development, exchange of experiences, intersectoral collaboration and linking opportunities, for the creation and development of technological innovation with high social and civic impact" (Haro, 2017).

In addition, the Epicentro focuses on the following secondary objectives: to promote existing public learning spaces in the region, which offer content related to the training of change agents and the generation of high-impact innovations; the empowerment of civil society for the generation of innovative ventures focused on priority social issues, through scalable solutions, with a sustainable approach, and supported by co-creative processes; and finally, to achieve the involvement of the four helices in the high-impact entrepreneurship ecosystem in an intersectoral manner (Haro, 2017).

The following table summarizes the activities conducted in the Epicentro each year, targeting the market of young people between 25 and 35 years of age, with a particular focus on the 16-20 age group. The large-scale events are held in a major event center, while the lesser (satellite) events are distributed to public spaces throughout the Guadalajara Metropolitan Area; and the activities seek to generate collaboration and collective work between actors of more than one propeller focusing on social problems.

Table 1. *Summary of activities conducted at the Epicentro Innovation Festival.*
Source: Self-elaboration based on Haro, 2017.

Activity	Description
Ideaton	Competition aimed at teams of senior high school students whose objective is to propose solutions to local problems aligned with the United Nations' Sustainable Development Goals.
Business development	One-on-one professional development dynamics for entrepreneurs, based on the "speed mentoring" methodology.
Training	Conferences and workshops specializing in entrepreneurship and innovation issues, open to different levels of participants.
Networking and business meetings	Spaces for networking and exhibition events in which networks of potential collaboration are generated.
Challenges and group dynamics	Creative games and competitions held during morning conferences and workshops.
Bonding with investors	Project pitch sessions in which entrepreneurs present ideas to be financed by investors.
Acknowledgement and certificate delivery	Possibility for attendees to receive recognition with curricular value, granted by the Ministry of Innovation, Science and Technology of the State of Jalisco.

Counseling for early stage entrepreneurs	Activities, workshops, talks, and conferences focused on nascent entrepreneurs.

Among the activities conducted in the Epicentro, the *Ideaton* program stands out, given its scope and transformative potential for a student segment poised to launch into entrepreneurship.

1.5.3 The *Ideaton* Program

Aligned with the United Nations' Sustainable Development Goals (United Nations, 2015), the *Ideaton* program is aimed at senior high school students between 15 and 18 years old, with the objective of fostering potential change agents through the generation of innovative solutions to the challenges of our society. Ultimately, the *Ideaton* seeks to promote an ecosystem of high-impact entrepreneurship in the early stages, and foster a culture of innovation through access to knowledge, tools, expert mentoring, and talent linkage, in line with the global trends in innovation and technology (Haro, 2018).

The structure of the *Ideaton* consists of five modules that are conducted over the course of a year: the *Preselection,* where SICyT makes a call to students of the state of Jalisco; the *Initial Competition*, where 1,000 students selected by a committee according to communicated criteria (including age, team gender balance, basic competencies, etc.; SEMS, 2018) compete in developing solutions as a first filter of finalists; the *Alignment Course*, aimed at homogenizing the competencies of the finalists; the *Techno-creative Follow-up,* focused on accompaniment by experts for the development of functional prototypes; and the *Final Awards*, where finished prototypes are presented for evaluation by judges, and the first three global places are chosen (see Figure 5).

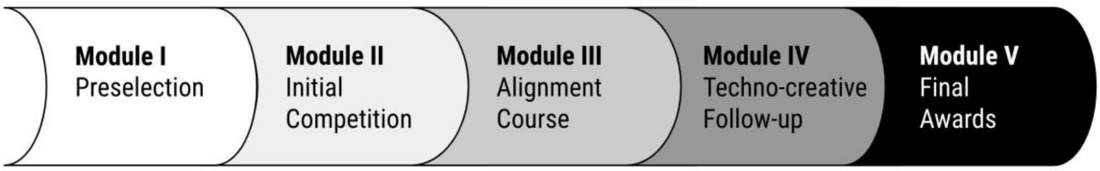

Figure 5. *The five modules of the Ideaton program.*

Throughout its five modules, the *Ideaton* aims at four main goals: first, to develop 21st century competencies (collaboration, creativity, critical thinking, computational thinking, and problem solving) through an inter-institutional competition; second, to promote the use of high-fidelity rapid prototyping (e.g., interaction through microcontrollers, sensors, and motors) (Bansemir et al., 2014), digital design and programming, through the use of innovation tools and methodologies; third, to familiarize participants with the challenges faced by the strategic sectors of the state, in accordance with the Sustainable Development Goals of the United Nations; and fourth, to generate a network of potential entrepreneurs in the innovation ecosystem of the state.

At the end of the five modules in its first edition, *Ideaton-2017*, the overall logistics of the program was analyzed, based on the above goals, in discussion sessions involving the co-organizers of the SICyT and UdeG's lead researcher in this project, Dr. Sanabria-Z, to identify opportunities to improve the technological impact and development of participants' competencies in the next edition. As a result, the following improvement objectives were defined for *Ideaton-2018*:

1. Characterize the role of instructors and facilitators.
2. Raise the technical level of the participants (by expanding the technological reach of the modules).
3. Characterize the role of the participants.
4. Increase the impact on the strategic sectors of the state.
5. Expand contact with and follow-up on students.

In order to pursue these objectives with an eye to *Ideaton-2018*, the co-organizers reconsidered the logistics of the event, and strengthened them through the creation of an international research group that focused on the development and evaluation of the competencies of both the facilitators and instructors, as well as the participants.

2. Method

Ideaton-2018, the primary context for this article, was co-organized by SICyT and UdeG. The new program reconceived the original conceptualization in terms of a collaboration involving interaction between the four helices of innovation: *Government* and *Academy/Research* as co-organizers, actors, and evaluators; *Industry* as sponsors, players, and evaluators; and *Users/Society* as volunteers and participants, represented by the students and teachers involved. The research design was conceived by UdeG's lead researcher and further complemented by an international group formed by members of Concordia University (CU) in Canada, and Université Côte d'Azur (UCA) in France.

A mixed-methods study was structured, with a strategic focus on inquiry (Creswell & Plano Clark, 2007), in order to converge qualitative and quantitative data which, at the end of the project, could contribute to characterizing the effect of the *Ideaton* as a process to develop and evaluate competencies of the 21st century, with a view to innovation and entrepreneurship.

The research was constructed from the perspective of pragmatism (Creswell, 2009), based on the following premises: the *Ideaton* program, as a process, results in social consequences whose *what* and *how* need to be researched for understanding and emancipation of its impact; the event is interrelated with the four helices of innovation, whose complexity can be better understood from several approaches, via mixed methods, instead of being limited to a qualitative or quantitative study only; and the novelty of the practices that occur during the *Ideaton* require flexibility on the part of the researchers, to collect and analyze data using different techniques and procedures.

In order to strengthen the *Ideaton-2018* edition, members of SICyT and UdeG's lead researcher analyzed the experiences in the previous *Ideaton-2017*, agreeing on the basic elements that should prevail in terms of logistics, content, and program scope; including the number of participants, use of a ideation board, number of hours per session, distribution of teams in the rooms, prototyping activity, roles of instructor and facilitator, use of projectors, award giving, the alignment course, the follow-up in *makerspaces*, and the final awards event.

Based on this analysis, a number of logistical and content requirements were identified, to be implemented in the second edition: 1) include prior training of instructors and facilitators regarding the logistics, and use of electronic devices and assessment instruments; 2) expand the length of the event from three to four days, with 250 participants per day; 3) increase the number of project themes from one strategic sector (e.g., *Health*) to eight strategic sectors (e.g., *Manufacturing, Agribusiness, Health*, etc.) per day; 4) design a digital platform to link and monitor the participants before, during, and after the event; 5) change from low-fidelity (e.g., cardboard and play-dough) to high-fidelity rapid prototyping (e.g., microcontroller, sensors, and actuators); 6) provide follow-up for all 1,000 participants, not only for the winners; 7) generate a system of continuous evaluation of the creation process during the different modules of the *Ideaton*, instead of only evaluating the final result; and 8) redefine and differentiate the activities in the five modules to be conducted over the course of a year.

In accordance with these requirements, the UdeG-CU-UCA group proposed several criteria for the research protocol: performance of the participating teams from Module II should be evaluated by generating instruments to evaluate 21st century competencies, based on the #CoCreaTIC tool; regarding the monitoring of participant teams, a digital platform should be designed and implemented; regarding the use of technologies, the self-perception of instructors and facilitators before and after the training should be studied; and lastly, for the preparation and operation of *Ideaton-2018*, it is crucial to manage the attendance of UdeG, UC, and UCA students *in situ*.

The logistics and research design proposal for *Ideaton-2018* was structured according to the aforementioned objectives and strategies. The aim of the event was to select three winning teams based on the process of developing functional prototypes, according to strategic sectors of the state, throughout the different modules of the program, for one year.

In the global project, the research methods for data collection involved participants as well as instructors/facilitators, and included an online questionnaire for participants; a participant ideation board, which was used as an instrument for retrieving the keywords teams used while co-creating prototypes; a questionnaire for instructors/facilitators; self-evaluation via the Socratic Wheel (Chevalier & Buckles, 2009) for instructors/facilitators and participants; and recollection of winners' testimonials through video.
Ideaton-2018 was designed to receive 1,000 students, between 15 and 18 years of age, from public and private senior high schools of the state of Jalisco. On the day of the event, the goal for each team was to develop a technological prototype through *maker* training facilitated by specialists, as a solution to a specific challenge aligned with the United Nations' Sustainable Development Goals and the mega trends in innovation and technology.

The instruments for the evaluation of learning and performance of the students were designed with consideration of the #CoCreaTIC observational tool, which focuses on measuring 21st century competencies, as outlined in the theoretical framework in Section 1.4.

Throughout the development and preparation of the five modules, several instruments were designed for application in the *Ideaton*, focusing on instructors' self-perception and mediation, students' self-perception and development of competencies, and the ideation process embodied by the teams in the guide scheme during the development of prototypes.

3. Results

In accordance with the research objectives, the results of the improvements incorporated in the five modules of *Ideaton-2018* are presented below.

3.1 Improvements incorporated in the Five Modules of *Ideaton-2018*

The iterative improvement approach of *maker education* is not only an educational objective of the *Ideaton*, but also a strategy in itself that can be improved after each year's event. Sessions involving SICyT members and UdeG´s lead researcher offered the chance to analyze opportunities for improving the impact of *Ideaton-2017*, and here we compare the contents of this event with those of the revised *Ideaton-2018*.

Module I, related to *Preselection*, maintained the objective of welcoming 1,000 students from the state of Jalisco. This module focused on a strategy for contacting institutions at the senior high school level, with potential participants for *Ideaton-2018*.

The improvements were meant to ensure a more directed and active dissemination of the call to recruit students. For both *Ideaton-2017* and *Ideaton-2018*, the selection of baccalaureates involved conducting an exploratory analysis (scouting) of the strengths of the targeted institutions in terms of science, technology, and entrepreneurship, through a review of the focuses of their study programs and the level of recognition achieved by the institutions. For *Ideaton-2018*, the scope of the call was increased to cover more regions in the state of Jalisco, outside the Guadalajara Metropolitan Area. Based on the analysis of potential senior high school graduates to be summoned, the recruitment agenda was defined according to the following strategies.

Regarding the means of contacting the representatives of the public and private senior high schools of the state of Jalisco, only email was used for *Ideaton-2017*; however, for *Ideaton-2018*, school representatives were invited to an informative breakfast where the details of the program and the impact of the event on their institutions was discussed. Further, while the invitations to *Ideaton-2017* were made through the institutions, face-to-face demo-workshops were implemented for the *Preselection* in *Ideaton-2018*, in order to identify student profiles best suited to the objectives of the event, and the students were directly invited to sign up. During the visits to the institutions, the event was promoted through motivational talks about the city in the year 2050, and presentation of a timeline illustrating global trends. In the end, an express demo workshop (1 hour) was offered, through the "four lenses of innovation" approach, where the participants proposed strategies for solving global problems.

Module II, *Initial Competition*, was designed to serve as the main filter for the 200 participating teams. Each team was composed of five members, and spent four hours in the competition. Below are three improvement vectors identified for *Ideaton-2018*.

The first improvement was the expansion of the strategic sectors. In *Ideaton-2017*, the program was executed in 3 days, with each day focusing on a single strategic sector: Day 1, *Smart Field*; Day 2, *Healthy life*; and Day 3, *Sustainable City*. For *Ideaton-2018*, the program was executed in four days (250 participants per day); and not only was the program expanded to include eight strategic sectors (*Manufacturing, Agribusiness, Health, Mobility, Fashion and Design, Electronics, Construction,* and *Gourmet*), but the sector activities were attended each day. The specific distribution was linked to the consequent selection of the space where the event would take place: the Palace of Culture and Congresses (Palcco) in Jalisco, one of the 10 largest theater venues in the world (see Figure 6).

Figure 6. *The Palace of Culture and Congresses (Palcco) in Jalisco where Ideaton-2018 took place.* (Source: Epicentro Festival de Innovación, 2018a)

Second, the advance training of the facilitators was improved. Improvements were also made in the methodology and scope of the development of proposals during the event. Based on the experience of *Ideaton-2017*, where a rapid low-definition prototyping exercise was conducted, using materials such as cardboard, scissors, and glue, for which there was no practical training of the facilitators and instructors, the methodology was reformulated with a view to implementing high-definition prototyping. Thus, *Ideaton-2018* included advance training of the facilitators and instructors on the procedure, and on the use and programming of electronic devices; the techno-creative prototyping was integrated, making use of a programmable microcontroller, electronic components, and a computer, as well as typical rapid prototyping materials; and an expert consultant in microcontrollers and electronics, *Robot in a can* (2018) was enlisted to support the teams as required on the day of the event.

The third improvement was focused on the organization of the presentations of the teams throughout the selective competition process. In the *Initial Competition* of *Ideaton-2017*, the objective was to reward 9 finalist teams from the 200 participants (3 teams per day). To this end, 6 rooms were arranged, among which roughly 65 teams of 5 students each were assigned per day (roughly 10 teams per room). Each team presented their final project to the instructor and the facilitators of their room, who in turn chose their 3 best teams, considering the possible impact of the product, according to their own experience and perception, for a total of 18 finalist teams per day. These went to the main auditorium to summarize their achievement for one minute and then answer questions from the judges, who chose three finalist teams per day based on their prototype and its impact.

In the case of the *Initial Competition* at *Ideaton-2018*, where 200 teams were also called, the objective was to reward 12 winning teams from 40 finalists, and also to acknowledge these finalists. In addition to the 40 finalists, 20 outstanding teams were recognized with a mention. (see Figure 7).

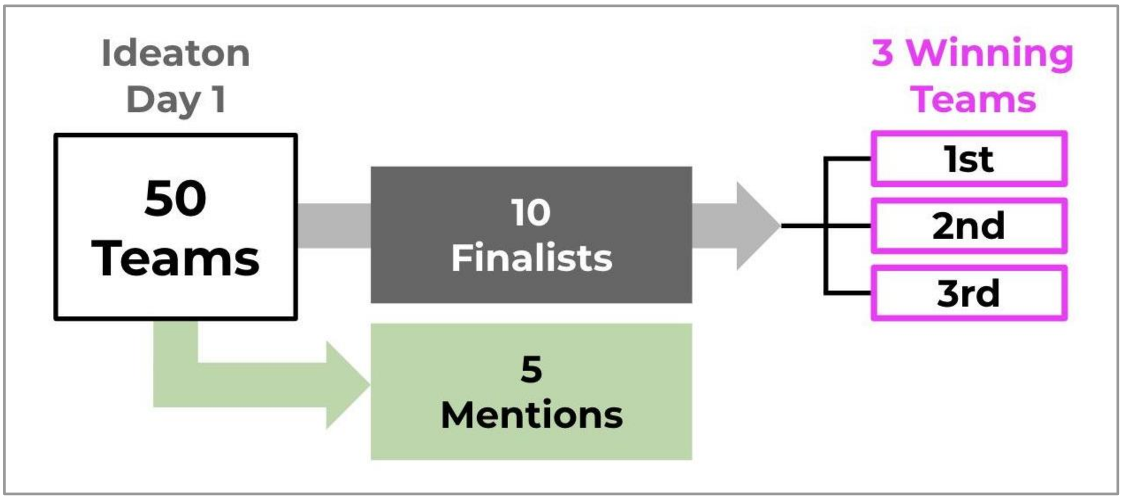

Figure 7. *Selection process for the three daily winners in the Initial Competition, Module II of Ideaton-2018.*

It should be noted that the finalists and honorable mentions (i.e., 60 teams in total) were given a techno-creative kit with a microcontroller, motors, and sensors, identical to those used in the event, in order to enable continued learning. Each day, 50 teams of 5 students were received (if any group showed up with less than 5 members, it was allowed to continue the process but not qualify as a finalist) (see Figure 8).

Figure 8. *Team of five participants with basic construction kit in Ideaton-2018.* (Source: Epicentro Festival de Innovación, 2018b)

The 50 teams were distributed to 10 rooms (5 teams per room) divided into the 8 strategic sectors: *Manufacturing*, *Agribusiness*, *Health*, *Mobility*, *Fashion and Design*, *Electronics*, *Construction*, and *Gourmet*. To best utilize the 10 rooms, each day, 2 of the sectors had 2 rooms each. For example, on Day 1, Manufacturing and Agribusiness each had 2 rooms, while each of the other 6 sectors had one room; on Day 2, Health and Mobility each had 2 rooms, and so on. One instructor per room evaluated the process of their 5 assigned teams, identifying the team with the best performance (finalist) and the second best (honorable mention), according to an evaluation instrument based on 21st century competencies.

The evaluation was systematically implemented by the instructors at three moments during the development of the prototypes in each room, and concluded with a final evaluation by three judges in the general auditorium (see Figure 9).

Figure 9. *Auditorium where the daily winners were announced in Ideaton-2018.*
(Source: Epicentro Festival de Innovación, 2018c)

During *Ideaton-2017*, there was no tool to monitor the development of 21st century competencies in relation to the technologies used and the proposed solutions. For *Ideaton-2018*, however, a digital platform was launched to facilitate interaction with the participants over the course of a year, through the five modules (Ruby et al., 2019). Prior to the *Initial Competition*, it was used to familiarize them with the topics of the strategic sectors and technologies to use; during the *Initial Competition* it served as a repository for consultation on the strategic sectors and instructions for the microcontroller; for Modules III, IV, and V, it was proposed as an adjunct tool for the participating teams, emphasizing the possibility of developing technological skills through the programming of the microcontroller and other electronic components.

In Module III, the *Alignment Course*, the objective of motivating and empowering the winners of the *Initial Competition* was maintained by standardizing their competencies in terms of technical knowledge and business vision. The proposals for improvement were as follows.

In *Ideaton-2017*, the 9 winning teams were assembled to take a 5-day course, while for *Ideaton-2018*, it was decided to invite the 60 teams that received the techno-creative kit, distributing the teams by days to enable more focused attention to the winners. During the course of the *Ideaton-2017*, digital design techniques, use of digital manufacturing equipment, assertive communication, and Business Plan concepts were covered, culminating in a summary presentation by each team. In *Ideaton-2018*, it was proposed to focus on the use of the microcontroller and digital design, as well as assertive communication and the Business Plan, with a summary presentation.

In *Ideaton-2017*, at the end of the summary presentations, businessmen and experts offered feedback on the projects. For *Ideaton-2018*, the generation of accompaniment alliances was added, as well as the possibility of receiving advice and access to online tutorials for the 20 teams that received honorable mentions.

During Module IV, focusing on *Techno-creative Follow-up*, the support program for the winners was maintained in *Ideaton-2018*, in partnership with *makerspaces*. The teams sought to fully develop their projects, both in functionality and aesthetics, and validate them with future users according to the latter's needs. The following improvements were proposed.

In *Ideaton-2017*, face-to-face support was provided by experts to the 9 winning teams of Module II. For *Ideaton-2018*, in addition to the face-to-face support for the 12 winning teams, follow-up was provided, in blended mode (in situ and virtually), for the 28 finalist teams and 20 honorable mentions, as well as online tutorials on a digital platform (website) for the rest of the participating teams. The winners of *Ideaton-2017* also served as "ambassadors" in *Ideaton-2018*, a role in *maker culture* generation that here involved participating in the different modules and supporting the new winners through the transmission of knowledge and experience.

For the winners, an alliance with 5 *makerspaces* was established for *Ideaton-2017* (increased to 12 *makerspaces* for *Ideaton-2018*), and with companies related to the themes of the winners' projects. Along these same lines, it was proposed to develop calls for financial support, provided that they could benefit the 12 participating teams. In addition, it was proposed to combine the digital platform that was launched for *Ideaton-2018* with a social network in order to monitor the 1,000 participants.

Module V, *Final Awards*, maintained the objective of rewarding the three best projects among the winning teams of the *Initial Competition* (Module II). The proposed improvements were as follows.

The final event of *Ideaton-2017* was held with the *makerspaces* that supported the projects during the follow-up to Modules III and IV. For *Ideaton-2018*, in addition to the *makerspaces*, 12 companies related to the themes of the winning teams' projects were added to generate potential alliances.

In this event, expert judges evaluated the presentations and prototypes of the teams that reached the finals event. At the end of *Ideaton-2017*, 1st, 2nd, and 3rd global places were rewarded, and the teams were appointed as ambassadors of that *Ideaton*. For *Ideaton-2018*, the generation of continuity alliances between the winning teams and the companies was proposed, in order to register and develop the teams' projects.

4. Discussion

In this article we discussed the content and evolution of the *Ideaton* events of 2017 and 2018. Through analysis of the experience of *Ideaton-2017*, the scope of the *Ideaton-2018* program was expanded in different aspects. The enhancement of the program involved members of the four innovation helices, to promote *maker culture*. The event was co-organized by members of the *Government* and *Academy / Research* helices. The involvement of the *Users / Society* helix was evident in teachers and student volunteers, who were trained as facilitators and instructors. In addition, integration of the *Industry* helix was achieved in the form of the alliances between businessmen and teams for the development of the teams' projects.

We can also see a greater impact in terms of the strategic sectors addressed, from one sector per day in 2017 to eight per day in 2018. From a research perspective, *Ideaton-2018* supported the contribution of international researchers, which enabled effective documentation and measurement of participants' skills and performance, and increased the social relevance of the *Ideaton-2018* model. In this sense, the development of 21st century competencies was oriented towards technological innovation, through the didactic use of programmable microcontrollers and electronic components.

4.1 21st century competencies assessment

The proposal to integrate the four innovation helices - *Government, Academy / Research, Industry*, and *Users / Society* - into the *Ideaton-2018* program is evidence of the program's potential to make a positive impact on the innovation ecosystem. The macro-dissemination of *maker culture* through the development of 21st century competencies such as collaboration, creativity, and problem solving lays the foundations for the innovation and entrepreneurship ecosystem in the medium and long term. However, it is necessary to generate mechanisms and instruments for longitudinal measurement of the performance of the participants during the harvest of entrepreneurship.

The inequality between public and private schools in Mexico, the lack of robotics laboratories, and the loss of opportunities to participate in innovation events or competitions, all have an impact on the development of 21st century competencies in that country. This contributes to new inequalities in the population that is marginalized and perceived as unqualified due to the school they attend, the neighborhood where they live, stereotypes of the minority group to which they belong, or gender differences. In this sense, the aim is that the proposed methodology will produce fair and balanced results for both the public and private senior senior high school teams, by involving co-creativity in the development of their proposals.

An innovation ecosystem is sustained in a complex way in its generation of a culture of innovation. Heavy dependence on the school system, which limits the ability of young people to develop their abilities, must be overcome by student empowerment that enables them to realize their unique potential. *Maker* events and innovation challenges help motivate teachers and students to develop an awareness of the potential for creation in such events. An example of the macro-dissemination of *maker culture* was evidenced by the *Ideaton* participants themselves, who greatly enriched their experience in these contexts, while continuing to develop their competencies with the collaborators. More specifically, the figure of "Ambassador of the *Ideaton*", which is awarded to the winners, is a mechanism for generating *maker culture*, inspiring them to share their achievements and knowledge with their environment.

4.2 The Value-Added Dimension in the *Ideaton* Concept

Organizing large-scale *maker* events is a challenging task because of the number of people involved, the resources such events consume in terms of preparation, labour, space, equipment, and time, and the fact that they tend to be highly competitive. As organizers, we are aware that participants of similar large-scale events (such as hackathons) often feel rapidly excluded from them, partly because they find them intimidating. We are also aware of common criticisms leveled at such events, that beyond exploring technologies, solving coding problems, etc., there is often little societal value in such events. We strive to avoid these potential pitfalls because our aim is to build 21st century competencies in both teachers and students, so that more notions of robotics can be integrated into their respective schools; and we want learners to think of social innovation as they tinker. The idea is not to create a marketable invention in a few days, but to create a prototype that has real social value, and provide an experience in which learners can appreciate the value of working in collaboration while going through the iterations of prototyping for innovation.

In addition, in the case of the Jalisco *Ideaton*, we wanted to ensure that no one left the event because they felt intimidated by technological skills they did not possess. To this end, we established the training of the trainers at the forefront of the event, based on the assumption that teachers who did not necessarily know how to code had to be trained to develop the fundamental knowledge needed to guide students. While we had no thought of training them to become expert programmers prior to the event, we did provide sufficient training to raise their level of confidence, or what Bandura (1990) calls the perception of self-efficacy, with coding and techno-creativity, which are key subcomponents for the development of 21st century competencies.

Providing sufficient preparation for the teachers (i.e., training the trainers) created a support structure for the 1,000 participating students, which established a critical basis of trust that, for example, enabled them to be guided and influenced by components of the four helices of innovation. First, the *Ideaton* took into consideration government policies with regards to education in the 21st century, focused on building excellence for global competitivity and the attainment of the United Nations' Sustainable Development Goals (2015). Second, it enabled students to experience components of the industry requirements necessary to prepare for the future of work, such as the need to become better problem solvers, work collaboratively, and think creatively. Third, it encouraged everyone involved in the events to address the concerns of academic researchers who are highly critical of integrating technologies for their own sake, and who demand multiple sources of evidence before admitting that such integration has a positive influence on learning. Fourth, it encouraged users and society to get involved and participate in the development of practicable real-world solutions to the problems they experience in real life. Finally, the evolving concept of the *Ideaton* contributes to higher quality of education for the general populace. For example, the organization of macro-dissemination events such as the *Ideaton* is a promising means of fostering *maker* education for a large number of learners; though, as aforementioned, such events present logistical challenges in terms of institutional support (e.g., transporting the large number of students to the event) and the management of facilitators.

5. Conclusion

The paradigm of Open Innovation 2.0, through the integration of the four helices, encourages individuals to acquire and exploit competencies that effectively respond to the labor and entrepreneurship expectations of contemporary and emerging industries.

Having explored the opportunities and challenges of *maker* education in relation to the competences of the 21st century, and the current limits of small-scale experimentation, it is now necessary to progress from experimentation to larger-scale events, pursuing macro-dissemination projects that enable a wide range of users to thrive in workplaces facing the daunting challenges of the 21st century.

The valuable educational activities developed in *maker* environments demonstrate considerable potential for the development of 21st century competencies. Despite this potential, however, we often find limited, small-scale experiments that develop in isolated efforts or only reach a limited number of users; for example, the EspaceLab in the Quebec City library, where, despite its location in a public, open library context, the number of people involved in *maker* education activities remains small (Romero, 2016). In other contexts, *makerspaces* have been developed in schools and other environments in which *maker* activities are intended to be accessed by the entire community; for example, the Fab Lab of the Faculty of Science at Côte d'Azur University and the FabAzur in France (Sanabria-Z & Romero, 2019).

The *Ideaton-2018* macro event provided a thousand young people with access to the resources and processes of the *maker* movement in education. Use of digital platforms to link and monitor the 1,000 participants is a promising strategy for generating synergy between them, and encouraging sustained interest in their projects, from sharing tutorials to calls and news related to innovation and entrepreneurship.

We live in a time of great uncertainty and massive technological change, in which automation, robotics, and artificial intelligence offer promise, yet at the same time threaten to transform our lives and jobs (Brynjolfsson & McAfee, 2012; Romero et al., 2018). Each community's approach to the use of technology for the co-creation of new technology, coupled with the development of 21st century competencies, offers the possibility of empowering citizens to become active members of the *maker* culture, integrating the four helices of innovation and exploiting these key competences in order to thrive in the creative economy.

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