REGGIO EMILIA ENGINEERING EDUCATION

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Abstract

How do we prepare future engineers to face 21th century challenges?
This paper confronts the issue of what it really means to be an engineer and how to design a learning experience that influence the process of formation of one's identity, as a professional and as a human being. In this effort we have been deeply inspired by a pedagogy directed to preschool and primary education of Reggio Emilia (Italy): Reggio Emilia Approach.
Starting from 2010, Project-based Learning was introduced in a MS&E capstone master degree class. New practices inspired by Reggio Emilia Approach were progressively implemented from 2011 to 2013. Every year, students completed a formal evaluation survey and answered to semi-structured interviews. The study reveals that there has been a significant increase of student interest toward the discipline. Students also showed to consider themselves more creative and confident about their capabilities.
This experience shows that it is not enough to design the education of the engineer, but we must consider as equally important the education of the human being and of the citizen, by focussing on relations, on collectivity and on participation.

Keywords: Creativity, Design Thinking, Project Based Learning, Design engineering

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1 INTRODUCTION

In the new global economies, there is a growing need for people who can create new things. People who have not simply gained knowledge – readily available on the Internet – but people that know how to use it in new ways. People able to deal with a wide sphere of possibilities, to understand problems, to find solutions, and to make decisions (Brierley, 2011). People able to connect together other people, information, tools, companies and cultures, because that is how you create more value today.
In this context, we find especially relevant Theodore Von Karman's words: *"Scientists discover the world that exists; engineers create the world that never was."*
Paraphrasing this thought, we can claim that creating the world is what engineers do. Therefore, future engineers are the most precious resource we have in facing the challenges of the 21st century, and how to prepare them for this task is the most pertinent question we face today.
Over the past years, the discussion about this issue generated a large number of interesting works, highlighting the major challenges that future generations of engineers will face and calling for transformational reforms of engineering education (Felder, Sheppard, & Smith, 2005; Splitt, 2003).
Furthermore, the pressure on engineering education to adapt and change keeps growing (Felder et al., 2005; Smith, Sheppard, Johnson, & Johnson, 2005), driven also by the two main stakeholders of the academic environment:

1. More and more young people are querying the validity of the accumulated knowledge they acquire in their formal education because they do not feel ready to engage in future society (Brierley, 2011). Engineering students, in particular, want to DO real engineering; they are very motivated when engaged in direct, hands-on experiences; also, they became aware that they lack the real life experience needed to make sense of complex concepts (Dym, Agogino, Eris, Frey, & Leifer, 2005; Lamancusa, Zayas, Soyster, Morell, & Jorgensen, 2008).
2. The business community wants engineering education to give a much higher priority to adapt education programs to professional practice; to promote young people's creative abilities; to develop teamwork and communication skills (Lamancusa et al., 2008).

In response to these challenges a number of reforms have been undertaken (Smith et al., 2005) such as the introduction of ABET (Engineering Change: A Study of the Impact of EC2000) and the establishment of the NSF EECs that are considered very important milestones on the path to a new paradigm for engineering education (Splitt, 2003).
At the same time, many university departments or individual educators are moving away from a curriculum centred on fixed knowledge, going towards more practical and flexible programs that are focused on teaching the students to cope, to discover, to invent, to adapt, to innovate (Smith et al., 2005).
In particular, Project-Based Learning (PBL) experiences - in which the learning takes place in the process of understanding and solving a real world project (Dym et al., 2005; Smith et al., 2005) - have been implemented in many universities. PBL is the dominant pedagogy for teaching design, which is considered one of the best approaches to cover most of the current pressing issues and opportunities for educating engineers who are capable of confronting tomorrow's challenges (Dym et al., 2005; Simon, 1998; Smith et al., 2005) and it has become increasingly popular among many engineering educators.
Despite the deep engagement of the engineering education community and of worldwide researchers, along with a high level of investment, many recent studies argued that further improvement are needed to prepare future engineers to meet XXI century challenges. In particular, there is still proof of growing academic disengagement among engineering students (Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008), with evidence that education programs are still failing at attracting and motivating them (Adams et al., 2011; Stevens et al., 2008).
In this regard, it emerges that one of the keys to better engage and motivate students is to support them in forming their identity as engineers (Adams et al., 2011; Stevens et al., 2008; Tonso, 2006), a fundamental issue often overlooked in studies of learning (Splitt, 2003; Stevens et al., 2008). Besides, a number of anthropologists argue that learning actually involves more than acquisition of skills and knowledge, but it affects also personal development (what type of person we become) and professional development (the way one understand him or herself in relation to a particular discipline. In this case, engineering) (Holland, 2001; Stevens et al., 2008; Tonso, 2006). The issue is complex and this is the purpose of this work: to join the effort in facing this huge but compelling challenge.

This paper is a qualitative study which describes, using phenomenography (Ashworth and Lucas, 2000), the experience we are doing in Reggio Emilia (Italy), while teaching design engineering in a MS&E capstone master degree class with a PBL pedagogy (Dym et al., 2005). To make a step forward we started from what it really means to be an engineer and, therefore, how to design a learning experience that individually and collectively influence the process of formation of one's identity as an engineer, and as a human being. And, in this globalized and fast-changing world where we are also redefining the concept of identity and citizenship (Brierley, 2011), we thought it was important to start from children and from their natural way of building their identity and their relation with the world. In this sense we have been deeply influenced by the Reggio Emilia Approach - one of the world most-influent pedagogical approach addressed to preschool and primary education (Edwards, Gandini, & Forman, 2012; Edwards, 2003) - which will be better described in chapter two.
In chapter three we present the main practices we have implemented, based on our interpretation of the identity of the young engineer, integrated in our context in Reggio Emilia. The common thread is a focus on relationships, as both a process of sharing experiences and intensifying connections.
In chapter four we discuss data and insights we gathered along the four years' experience, using data from a formal evaluation survey conducted by our University and from semi-structured interviews.
Finally, we outline implications for further research and for new engineering education's practical applications.

2 THE REGGIO EMILIA ENGINEERING EDUCATION (REEE) VISION

2.1 Background

At the University of Modena and Reggio Emilia, we have been teaching Engineering Design for four years with a Project-Based Learning (PBL) pedagogy (Dym et al., 2005) in a course called Business Processes Engineering, which is a capstone master degree class offered at MS&E major. In this course, students are required to solve "real world" problems provided, along with expertise, by not-for-profit organizations.
Despite the remarkable results, we had evidence from students' evaluation and our observations, that further improvements were necessary. First, the process of requiring students to engage in open-ended problem solving, either individually or in groups, can be frustrating, as students are not educated to think creatively or are not confident with their creative skills. Second, when students develop the creativity required to envision the changes, they would not have the human capabilities and self-confidence necessary to impact their own future.
Thus, we started seeking new inspirations to face this issue and to give new opportunities to nurture young engineers' human and professional identity. In this effort, we had the strong feeling that, in order to pursue a paradigmatic shift, engineering education could find solutions and energy from childhood and children learning process, with the awareness that, as engineering studies, childhood is not a separated stage in the human identity and life, rather it is the best representation of its potential (Edwards et al., 2012). In this exploratory process, the close exposure to the Reggio Emilia Approach, one of the world most influent pedagogies for children education (Edwards et al., 2012; Edwards, 2003), have had a meaningful impact on our ideas and decisions. In fact, Reggio Emilia Approach main aim is to reinforce the child's sense of the possible, in order to nurture a "resourceful child" that can generate changes in his/her society and becomes a *"producer of culture, values, and rights"* (Edwards et al., 2012).
The concept and the output of this approach were both fascinating and enlightening to us. All its values seemed to fit also to higher education and to engineering education in particular. Most importantly, they also seemed to fit very well with our identity as educators.
Thus, we decided to redesign the Business Processes Engineering course making it a laboratory to develop a new paradigm of education, inspired by both PBL design engineering and Reggio Emilia Approach. We call this approach "Reggio Emilia Engineering Education" (REEE).

2.2 The "Image of the young engineer"

The Reggio Emilia Approach is an education pedagogy, directed at preschool and primary education, that reflects a social-constructivist view of learning and aims to nurture children's natural needs, creativity and curiosity (Edwards, 2003). Loris Malaguzzi, who started it with a group of parents of

Reggio Emilia after World War II, built a powerful image of the child: intelligent, creative, full of wonder, and naturally competent in forming relations with the world (Edwards et al., 2012):
"Our image of children no longer considers them as isolated and egocentric, does not see them only engaged in action with objects, does not emphasize only the cognitive aspects, does not belittle feelings or what is not logical, and does not consider with ambivalence the role of the affective domain. Instead our image of the child is rich in potential, strong, powerful, competent, and most of all, connected to adults and other children." (Malaguzzi, 1993, p. 10).
That's why he envisioned an "education based on relationships", that would strengthen the child's sense of identity by triggering and supporting his or her relationships with peers, with adults, with society, and with the environment (Malaguzzi, 1993).
With these premises, it would have been a great mistake for us to think that we could somehow just import Reggio Emilia Approach practices into engineering education. Our environment and our aims are different, and so must our actions be. Thus we started by understanding and giving an identity to our own context. Moreover, just as the Reggio experience starts out from the image of the rich child, so we want to build and hold our image of the young person, and specifically of the young engineer.
In this sense we noticed that researchers and educators, who have studied engineering education deeply, have pointed out not so much the limits and weaknesses of engineering students, but rather their limitless talents and potentials, and their increasing interest in how they can help to change the world (Splitt, 2003). Besides, today's young engineers are born into an endless sphere of possibilities. They are engaged not only to make their choices and decisions as never before, but also to create new alternatives.
This opens a number of opportunities for further research and practical actions, yet educators have not properly embraced these discoveries: in its ideals and in its everyday activities, the current engineering educational system still struggles in nurturing the nature and the potential of human capability.
And this is why, in facing the critical question *"What is our image of the young engineer?"* a simple, steady consideration came to our minds: young engineers, as well as all young people, are not a needy group to be protected, rather they are a resource to be unleashed to its full potential; in other words, they are not the engineers of the future, but the engineers of today.
Thus, we designed a vision for the image of young engineers, since we believe that all young engineers have different capacities, talents and interests; they each have different pasts and different futures, and to this extent, they are individuals who bring their rights, their desires, and their capabilities with them, into the educational environment and into the society. They can innovate, create, make, interact, reflect, connect, shape, and participate.

Young engineers are capable to envision the future and to shape it. They have creative energies and interest to improve the context, quality and prospect of human life.

From this moment on, our mission in Reggio Emilia is to design an educational project that realizes the full potential of the young engineer, which shall not be alone in this process of growth and development. Rather, he or she is protagonist in a collective effort of active discovery of his or her self, supported and encouraged by the wider community.
Along the path to pursue this vision, our image of the engineer addresses three equally important functions, briefly described here and developed in this paper:

1. The concept of forming one's identity is often considered to be "double-sided" (Holland, 2001), meaning that not only one's perception of his/herself helps to build an identity (e.g. as an engineer), but also do the ways that one is positioned by other people and institutional practices (Holland, 2001; Stevens et al., 2008). In particular, Stevens and colleagues (2008) argue that differences in how institutions officially identifies students as engineers had profound effects on students' identification of themselves as engineers and on their futures and commitment to the field. However, in accordance to a number of researchers (Adams et al., 2011; Splitt, 2003) the image of engineers in the public opinion is poor: they are expected to solve problems defined by others, never to set the agenda for problems to be solved. Besides having a bad impact on engineers' identity, engagement and motivation, this is obviously impeding and deterring the desired talents. Therefore, by conveying a new meaning of the engineer and of engineering education, we aim to excite students' imagination, help them realize that they can give full expression to their dreams and their talents, and thus improve their perception of themselves.

2. As in a design project and as in the Reggio Emilia Approach, the path to solve our challenge is all but linear and clear, and there is no predefined outcome (Simon, 1996). Therefore, we need to adhere to a clear and visible core vision that guarantees coherence in our decisions, actions, and ongoing professional growth. Furthermore, it acts as a source of inspiration and guidance to stimulate change and progress.
3. We know it is necessary to be student-centred, but we do not feel that is enough. As described above, we aim to impact the process of identity formation of an engineer under two dimensions: individuality and collectivity. Thus, we consider all components of the social and professional sphere of engineering students as being central to their education. By creating a culture of social concern, we aim to assure attention to the issue of education, and to activate the participation of families, friends, citizens and professionals.

Certainly, we also approach the vision with a design character: it is a construction in motion that provides direction but that is itself subject to revision; neither means nor goals are fixed, but open to new research, new perspectives, and new understandings.

3 THE REEE IN PRACTICE

In this chapter, we describe the four key practices we have implemented, based on our interpretation of the identity of the young engineer, integrated in our context in Reggio Emilia.

3.1 Focus on relationships

We designed every learning experience with a strong focus on relationships, as both a process of sharing experiences and of intensifying connections. Constructivist theories argue that learning is a social activity and can't happen alone (Minneman, 1991). Specifically, researchers in engineering education agree that teamwork - whether using discipline-centered or interdisciplinary teams, in face-to-face or in virtual contexts - has beneficial effects on learning (Smith et al., 2005), and project-based courses are crucial at improving students' design and communication skills (Dym et al., 2005).

What we want to stress, in addition to what is well known, is the importance of relations that take place outside the classroom also. It is undeniably necessary to consider the knowledge and skills that students acquire independently of and beside to schooling, and this knowledge originates particularly from their social growth, in all its levels and environments. Most importantly, instead of thinking of young students as autonomous actors who live out their educational experience just by expressing themselves, anthropologists of education have long argued that one's sense of oneself is formed out of a double-sided process of positioning oneselves and being positioned by others, thus it also emerges from human relationships, including peers, families, friends, and communities (Stevens et al., 2008; Tonso, 2006).

The focus is in involving students' social network in their learning experience and environment, and in promoting the diversity and richness of it by creating an educational environment that is not only student-centred: we aim to continuously maintain and integrate our network of communication and interactions with families, citizens, researchers and professionals.

The most characterizing activity of the class, and the most important trigger for creating new relations and enhance old ones, is strictly related to PBL and Engineering Design (Dym et al., 2005). In fact, we invite not-for-profit organizations and public institutions to provide real world challenges to engage small teams of students in a three-month intensive activity, working closely with the organizations. Most projects challenge the students to solve innovatively either organizational or business issues (e.g. design a better and quicker experience for a patient of a hospital). The challenge's objectives serve as a powerful, ever present guidance, giving the student great motivation because they know how important and impactful can be their contribution.

Partnerships with outside organizations and individuals are essential to the kind of engineering education development we are advocating. Starting from the awareness that real issues given by companies represent a primary motivation for students (Dym et al., 2005), we decided to work only with non-for-profit organizations partly because promoting social good is very valuable to many engineering students (Dym et al., 2005; N.A.C.C.C.E., 1999), partly because we noticed that non-for profit organizations are much more likely to need and implement the solutions provided by the students, making them more confident about their skills and capabilities.

Furthermore, these projects are great catalysts for various activities and encounters:

- Students meetings within the team, which is composed of 4 to 5 people for optimal communicative efficacy. The project serves as a powerful driver to awaken the talents of exchanging ideas, creating meanings, communicating with others, thinking and expressing one's thoughts.
- Meetings with members of the organizations. They are key in promoting a two-way direction of interaction between young engineers and professionals, providing opportunities for practicing deep communication skills, which are crucial to learn and to engage in the professional environment.
- Meeting with educators. We meet weekly with the students in large groups to discuss common issues and in small groups, where the single team shares its insights, findings, and problems about their own project and context. Throughout the projects, we as educators try to intervene actively in the project content as little as possible. We focus instead on the process, continually revisiting what has been happening, discussing the findings among ourselves, and then deciding how to support the student exploration.
- Mentorship. We invite several professionals from different fields to mentor the teams of students. Each team has one mentor that supports them all throughout the project, serving as a bridge toward professional life and as a resource when they seek feedback, advice, or direction.
- Cooperation with other departments or universities. We host (and we visit) other departments or other universities classes for intense workshops, in which young engineers have the opportunity to collaborate with students from different disciplines and cities, to enrich and contaminate projects and ideas of both sides with more than one perspective. Partnerships between departments and schools enhance and extend the experiences of the students, giving new energy and ideas to our teaching, and are also great opportunities to enlarge the network of relationships (to name a few: Department of Management of Arizona State University; Department of Computer Science of University of Bologna; Design School of Milano Polytechnic).
- Seminar with experts. These encounters take the form of an interactive seminar or lecture (we call them "conversations") with hosts from universities from across the world, and are followed by a refreshment to go on with informal conversations. They are open to the public and are tailored to increase everybody's knowledge of subjects or issues of common interest and to increase opportunities to form new connections among students, researchers, companies, and citizens.
- Public presentations. Where students present their achievements to the organizations, to the public and to the press.

In this rich and complex scenario, both the professionals, educators and students are complementary: they ask questions to each other, they listen, and they answer. In addition, because of this vibrant network, young engineers (and everyone else) have the opportunity to learn through their communications and real shared experience. It means that the system has a virtually autonomous capability to educate. It is indeed a constant and durable presence, particularly impactful when progress becomes difficult.

3.2 Respect the potential of young engineers

It is important to describe our role as educators, as it is principally our responsibility to engage students in learning and it was our task to design and realize the learning experiences that are described in this paper.

The role of the educator is strictly related to the role of the young engineer as learner. By creating a tangible image of the young engineer's talents, rights, and possibilities, we come to understand what actions and instruments are needed to nurture his or her full potential. And, as we agree that young engineers are resourceful and capable of constructing their own powers of thinking, our role as educators starts from considering them as producers, not as consumers of knowledge. It means we are not controlling or directing the students towards goals, which are external to them, rather we are involved as partners in their learning experiences and we respect the opinions of the group and of the individual. It is important to keep them away from considering us as judges, but rather as participant learners, which is more often the case.

Like Piaget (1976) and then Malaguzzi (1993) we agree that the aim of teaching is to provide means by which the learning can take place. Therefore, we do not aim to lecture young engineers in an abstract, generalized way, because we noticed that when students work on a problem that matters to them, they would naturally encounter issues they will want to analyze and understand. At that point, we do not offer answers or ready solutions, but instead help students to focus on the problem and formulate different hypotheses. Sometimes we act as partners, sometimes we introduce new elements and resources, sometimes we offer strategies to get "re-launched" because they are "stuck", sometimes we share feelings and thoughts, sometimes we even help them uncover more questions and avenues.
Thus, our role as teachers is not really to "facilitate" learning in the sense of "making it smooth or easy" but rather to stimulate it by opening opportunities and making problems more complex, involving, and compelling. However, we always need to keep in mind that the process should focus around an active self-discovery rather than a behavioral response to given stimuli.
Of course, we, like the students, feel the need to evolve by keeping in step with a changing society and grow in our competencies, and just as we see young engineers learning best through communication, conflict and co-action, so we must also consider ourselves to learn in this way. Thus we have a tendency to engage each other in deep dialogues, mutual criticism and self-examination of our teaching instruments and behavior, and to activate our network of worldwide academic people to bring new considerations, ideas, and opportunities into our practices.

3.3 Support diverse languages

Dym et al. (2005) observed that engineers need to think and represent design and engineering knowledge through several languages beside mathematics (meaning verbal or textual statements, graphical representations, shape grammars, features, mathematical or analytical models, numbers, etc…). They serve different purposes and moments in a project.
Similarly, Reggio educators believe that children have "100 languages" for representing, expressing, and discovering ideas and feelings (Edwards, 2003): meaning words, movement, drawing, painting, building, sculpture, shadow play, collage, dramatic play, music, to name a few that they systematically explore and combine.
Inspired by both approaches we came to think that a resourceful young engineer must be enabled to construct his or her powers of thinking through the synthesis of all the expressive, communicative and cognitive languages. And in order to do so, we intend to fully overcome the division between arts and science that have deeply affected our educational system (N.A.C.C.C.E., 1999), by promoting the penetration or infusion of artistic and humanistic disciplines into the technical environment of our Department of Science and Methods for Engineering.
The most meaningful action we took to pursue this task, is the arrangement of a number of elective workshops to give young engineers the opportunity to discover their own creative strengths (dance, theatre, graphics, video, music, process modeling to name a few of them.).
These workshops are intended to be places for discoveries, research, and to learn more about oneself.
It is a *learning by doing* that is developed and enriched by working with outside professionals and mentors who are prepared to share their experience.
Nevertheless, they are not intended to be a sort of separate lectures for the students, or a privileged space where it is possible, there and only there, to experiment with the given "language". Rather we reinforce the developed capabilities during the lectures and the course of the project, developing the deliverables with re-discovered talents. These activities are moments during which student's different interests can be explored by them and studied by us. What is important is to help young engineers find their own way of creating, discovering, and exchanging one's talent with others. How the learning happens is not as important as whether that learning encourages students to try to learn even more.

3.4 Convey a new image of young engineers

A very important activity of our work in Reggio Emilia is to make students' and educators' work visible and subject to public awareness. On a practical level, our main instrument to accomplish this task is the pedagogical documentation, intended to be two-sided:

1. We, as educators, collect photos, anecdotal notes, videos, and other meaningful documents, to trace the experience of each student during the course. This includes student's initial expectations, presentation of the challenges given by companies, team-building activities, halfway prototypes, feedback of weekly meetings, final presentations of the project.

2. The students are also invited and motivated to document constantly their progress, in order to have one more perspective of the overall experience. They are given a blog on the internet, to update weekly with photos, videos and insights about what they do, what are the main problems they face, and what choices they make as they proceed. Of course, they also prepare exhaustive presentations in the course of their project experience, to show the outcomes also to the organizations and to the wider community.

Both streams of documentation, exclusive of few private information, are also shared with the city, becoming useful tools for research, exchange, professional development, planning, and community participation. More precisely, they simultaneously serve two purposes, cultivating the two sides that form one's identity, introduced in chapter two of the paper (Holland, 2001):

1. **The perception of one's own self.** Documenting the progress of the project fixes the information in everyone's memory, it helps outline the stages the students went through, and thus to understand their innovation process. When revisiting the stages of the project, students can reflect on themselves as individuals and group members, and thus incorporate their memories into their self-identity. Further, they realize that they can create ideas that are valued and that their ideas can become reality.
2. **The way one is positioned by others.** By making students' work both visible and subject to public awareness and discussion, the documentation provides the possibility for young people to gain new prestige and legitimacy in society. In fact, well-documented examples of complex projects and high-level achievements of the students can promote the new image of a competent young engineer. The flow of documentation and presentation, we believe, introduces families, citizens and professionals to a quality of knowing that changes their expectations tangibly. They re-examine their assumptions about their roles and their views about the young engineers, their experience and their life at university and take a new and more interested approach toward the whole university experience.

4 ASSESSMENT

Since its beginning four years ago, the Business Process Engineering course went through a radical transformation that formed the experience we are describing in this paper. It started in 2011 with the introduction of Engineering Design with a PBL pedagogy (Dym et al., 2005), and it continued in 2012, with the implementation of new actions inspired by Reggio Emilia Approach, and in 2013, with a better integration of the two approaches. Today we can look back and discuss data and insights we gathered all along the path. In order to evaluate the effectiveness of this laboratory we chose two research methods to serve two different purposes:

1. On the one hand, we analyzed the formal survey conducted, every semester, by our University, which asks every student to voice their opinion about their experience in each class they attended. More specifically, we are interested in students' assessment about how much the class stimulates and motivates their interest toward the discipline. In other words, we want to measure the students' engagement.
2. On the other hand, we conducted face-to-face individual interviews, with open-ended questions that would still encourage students to reflect on the nature of their human and professional identity development. Because, as Schon (Schön, 1987) argues, we believe that the best way to support students development of real skills is to combine experience with coaching and opportunities for guided reflection.

4.1 Engagement

In Table 1 we observed the extent to which the gradual development of our pedagogy impacted students engagement level for the academic years 2010, 2011, 2012, and 2013 (only engineering design PBL pedagogy was implemented in 2011, Reggio Emilia Approach was gradually introduced from 2012 to 2013). Data are extracted from a formal survey conducted by the University, where students are asked to rate from 1 to 10 a list of criteria, and they refer to the question: *Does the teacher stimulate and motivate your interest in the discipline?*

Table 1

Academic Year	2010	2011	2012	2013
Engagement Average	7.38	8.00	9.00	9.15
Standard Deviation	2.38	2.00	1.44	1.58
N° of Respondents	42	37	33	33

The study reveals that there has been a significant increase of the average rate over the years, which corresponds with the decreasing of the standard deviation. These results indicate that - since the engineering design PBL component remained constant - the more the pedagogy was influenced by Reggio Emilia Approach (and the more experience we gained) the more students appreciated the experience and their interest toward the discipline increased.

4.2 Human and professional identity development

The second perspective of our research is based on face-to-face individual interview, in which we invited each young engineer to evaluate how and how much the course impacted his or her own skills as an engineer and as a human being. The interview was designed in order to understand if, how and how much the course influenced each young engineer's perception to have creative energies, to be able to envision the future and competent to build it.

Students were provided with the time, space and support to reflect about themselves, about the experience they have had, and why and how this have affected what they have learned.

When we asked them about how and why the course had changed themselves, many found this a weird question, since they did not generally think about the impact that a university class has on their identity. However, as they dived deeper and deeper into their new prospects, students expressed surprise while also realizing the level of their own personal, professional, and human development.

Looking at students' reflections we observe that they feel more open to challenges, more capable to work with their peers in unusual situations, and more engaged because they realize they can make their own choices, and that they can easily try out what they have in mind:

> *"This class gave us evidence that we can make things, we reached a point in which when we give ourselves a challenge we feel strong enough to face it. We got through a difficult path and, in spite of the pressing deadlines, we made it. This improves our self-esteem!"*

Elective workshops have proved to be subversive, generating complexity and new tools for thought, and offering opportunity to set new connections and tighten existing ones:

> *"The workshop of dance was very useful because we had dialogue and exchange with girls from another environment (outside university) and it was useful to see different points of view... It was also useful in making the class group more united in an experience far from school desks."*

Students also demonstrated a better understanding of the creative process; in particular, they recognize it as a way of thinking that can be enhanced by multiple experiences:

> *"By learning so many things and so many tools, the class helped me to see things in an integrated way, and then you can create connections. Growing up I had become less flexible: maybe I have an idea and that idea can generate more ideas, but I'm not able to do that automatically... With this class I retrieved a little this ability to connect ideas automatically."*

The collaborative environment offered the students the opportunity to realize that their own ideas are different and that they hold a unique point of view. Students reported significant improvements in their listening skills also, as they recognize the value of another's point of view and interpretation, and appear to be open to differences and to better trust the collectivity:

> *"I was already secure and self-confident but this course helped me refocusing my confidence... Now I feel more complete because I trust other people and I trust my team. Because listening to others can be very fruitful"*

From our analysis, we can claim that the young engineers were able to internalize the seeds of the vision we were proposing through the experience of the class, showing creative energies and interest to improve the context, quality and prospect of human life and feeling able to envision and shape the future.

As a final consideration, we realized that by helping the students reflect, by offering support and dialogue to them, by observing, documenting, and discussing these processes, we as educators are also enabled to discover our full potential as learners – in this case learning how to educate.

5 CONCLUSIONS

This experience opens the path to an engineering education that goes beyond economic objectives: it must not only prepare students to be capable engineers, but also enable them to discover their inner self, as individuals and as citizens. In addition, as the research of one's identity is strictly related to the interaction and confrontation with others, engineering education needs to focus on relations, on collectivity and on participation.

To embark on such a transformational experience requires high commitment, energy and resources, together with the awareness that it will involve primarily a personal and professional change. It is important to count on a wide, involved, local and global community, and to continuously maintain and integrate the network of communication and interactions among students and colleagues. Indeed, it is a very demanding and difficult journey full of pitfalls and obstacles.

Students might find these activities too stressful and demanding in a first moment, feeling uncomfortable with facing uncertainty and asking for directions that are more precise. They might also express their difficulties in coordinating their academic commitments.

Colleagues might challenge the approach, as it is not posing an upper bound on students' involvement to the detriment of more standard courses.

Indeed, our society needs to continuously embrace change and be aware that 'holding on' leads only to a dangerous status quo. This means we need to never stop cultivating experimental, open-ended educational projects, and to keep projecting our values, dreams and images for the future. Because we have a responsibility to continue moving forward and to evolve by keeping in step with a changing society, we definitely feel the call of Jerome Bruner (Edwards et al., 2012): *"Today, Reggio Emilia needs to find a way to generalize the most of what the city has done until now, to influence educational system on all levels."*

REFERENCES

Adams, R., Evangelou, D., English, L., De Figueiredo, A. D., Mousoulides, N., Pawley, A. L., Schiefellite, C., Stevens, R., Svinicki, M., Trenor, J. M., & Wilson, D. M. 2011. Multiple Perspectives on Engaging Future Engineers. Journal of Engineering Education, Vol. 100, No. 1, pp. 48-88.

Ashworth, P., & Lucas, U. 2000. Achieving empathy and engagement: A practical approach to the design, conduct and reporting of phenomenographic research. Studies in higher Education, Vol. 25, No. 3, pp. 295-308.

Brierley, D. L. 2011. Educating The Art of Life: Resilience and Creativity in Contemporary Education. In t. Q. o. C. G. i. t. E. Parliament (Ed.): European Council for Steiner Waldorf Education

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. 2005. Engineering Design Thinking, Teaching, and Learning. Journal of Engineering Education, Vol. 94, No. 1, pp. 103-120.

Edwards, C., Gandini, L., & Forman, G. (Eds.). 2012. The Hundred Languages of Children: The Reggio Emilia Experience in Transformation (3rd ed.). Santa Barbara, CA: ABC-CLIO, LLC.

Edwards, C. P. 2003. " Fine Designs" from Italy: Montessori Education and the Reggio Approach. Montessori Life: Journal of the American Montessori Society, Vol. 15, No. 1, pp. 34-39.

Felder, R. M., Sheppard, S. D., & Smith, K. A. 2005. A New Journal for a Field in Transition. Journal of Engineering Education, Vol. 94, No. 1, pp. 7-10.

Holland, D. 2001. Identity and agency in cultural worlds. Cambridge, MA: Harvard University Press.

Lamancusa, J. S., Zayas, J. L., Soyster, A. L., Morell, L., & Jorgensen, J. 2008. 2006 Bernard M. Gordon Prize Lecture*: The Learning Factory: Industry-Partnered Active Learning. Journal of Engineering Education, Vol. 97, No. 1, pp. 5-11.

Malaguzzi, L. 1993. For an education based on relationships. Young Children, Vol. 49, No. 1, pp. 9-12.

Minneman, S. 1991. The Social Construction of a Technical Reality. Stanford University, Stanford, CA.

N.A.C.C.C.E. 1999. All Our Futures: Creativity, Culture and Education, London: Department for Employment and Education.

Piaget, J. 1976. To understand is to invent. New York, N.Y.: Grossman.

Schön, D. A. 1987. Educating the reflective practitioner: Jossey-Bass San Francisco.

Simon, H. A. 1996. The Sciences of the Artificial (3rd ed.). Cambridge: MIT Press.

Simon, H. A. 1998. What We Know About Learning*. Journal of Engineering Education, Vol. 87, No. 4, pp. 343-348.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. 2005. Pedagogies of Engagement: Classroom-Based Practices. Journal of Engineering Education, Vol. 94, No. 1, pp. 87-101.

Splitt, F. G. 2003. The Challenge to Change: On Realizing the New Paradigm for Engineering Education. Journal of Engineering Education, Vol. 92, No. 2, pp. 181-187.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. 2008. Becoming an Engineer: Toward a Three Dimensional View of Engineering Learning. Journal of Engineering Education, Vol. 97, No. 3, pp. 355-368.

Tonso, K. L. 2006. Teams that Work: Campus Culture, Engineer Identity, and Social Interactions. Journal of Engineering Education, Vol. 95, No. 1, pp. 25-37.