

Set-Based Concurrent Engineering (SBCE) Game Teaching Initiative.

Introduction, motivation, description, effectiveness and results.

This proposal wants to bring to the committee's attention a serious game developed by Monica Rossi (Assistant Professor at Polimi) and Sergio Terzi (Associate Professor at Polimi), called *SBCE Game*. The game has been developed to teach Set-Based Concurrent Engineering (SBCE), a specific niche concept within the lean product development field. The SBCE Game is the result of about 6 years of joint research activity conducted by the authors, strongly based on both literature and industrial applications.

SBCE is the most challenging yet promising approach proposed within lean product development. Though there are still open issues linked to its application in industry and its fully understanding in literature. There is a need of increase SBCE appreciation and awareness, nowadays while SBCE is often confused with the mere parallel development of design alternatives, only few authors and practitioners recognize full SBCE functionalities and features of developing reusable knowledge and enabling the ability to learn within designers and engineers. Also there is a call for deeper exploration of SBCE benefits and development of SBCE application methods to support SBCE implementation on practice. Universities and scholars have the duty to fully understand first, and communicate this understanding to both companies (practitioners and master executive students) and the next generation of designers, managers, and engineers (today's student). This project covers these challenges, with a serious game delivered face to face and facilitated by the authors or trained trainers.

As stated, the SBCE is a powerful teaching tool for both master and post-graduate students, as well as practitioners. The SBCE Game is structured in two phases. The first leads the players toward the traditional so-called Point-Based Concurrent Engineering (PBCE). Players are actively engaged in designing, building and testing a simplified airplane structure using Lego bricks, with the aim to satisfy a list of known customer requirements. This first phase follows the traditional product development approach and wants to emphasize the trial and error approach, highly diffused in modern thinking and industrial approaches.

In the second phase, main tools and enablers of the SBCE approach will be given to the players, such as trade off curves and limit curves. They will experience how this lean approach supports the design process in meeting simultaneously given customer requirements and known technical constraints, through the progressive elimination of weak alternatives. The second phase is played using paper documents representing trade off curves and technical constraints.

The main learning objectives achieved with the game are:

- Introduce the concepts of SBCE and its application to product design
- Demonstrate the challenges of meeting customer and design requirements
- Demonstrate the importance of common tools and lean product development enablers used to execute SBCE principles and process
- Demonstrate the performance benefits of SBCE compared to PBCE in terms of reducing time to market, reducing development cost, improving visibility, improving flexibility, improving confidence, and enhancing knowledge based design
- Teach the importance of use and reuse of technical knowledge, introduce the concept of design spaces, of known and unknown knowledge matrix.

- Suggest how to identify and eventually cover knowledge gaps hence how to focalize innovation efforts within product development initiatives.

The game has been played by more than 100 companies all over the world, more than 500 practitioners, more than 500 MSc students. A high percentage of people playing the SBCE Game experience this innovative concept for the first time. Though they get the revolutionary idea behind it and they take away important lessons learned for their (actual or future) organizations and for their own understanding and learning, that potentially will affect their daily practices. The main innovation behind SBCE is its ability to revolutionize the traditional industrial paradigm by introducing a different perspective when designing new products, that could be refer as a knowledge driven design approach that mitigates product development unsuccessful performance. Moreover it promotes a high formalization and reuse of knowledge, that sometimes looks so trivial but yet poorly adopted within organizations, by using visual knowledge as trade off curves and design spaces. The SBCE Game opens people's eyes on innovative ways to look at the daily design challenges company face.

Some examples of SBCE Game teaching experiences include the following.

Industrial experiences

- 1 day SBCE Game session with 12 practitioners from 10 different companies in Michigan during the "Designing the Future Summit" on 19th June 2018.
- 1 day SBCE Game session during the "Lean European Summit" in Venice in October 2017.
- 2 days SBCE Game session with over 15 companies in Barcelona hosted by Instituto Lean Management on 30th-31st March 2017.
- SBCE Game session with Lean Enterprise Institute Israel with about 5 companies and more than 40 people in total, in May 2015 and February 2016
- SBCE Game session at University of Buffalo, over 10 companies attending, in May 2015 and September 2015
- SBCE Game session every December since 2013, hosted and invited by CRAFT LEAN, industrial programs for lean product development, Nederland.
- Yearly, since 2015, Lean product development training and SBCE session hosted by Confindustria Bergamo, 16 companies attending.
- Private SBCE Game sessions within specific companies since 2013.

Executive Master Programs

- Since 2014 the SBCE game is used during the Lean Product Development module of the Lean Six Sigma Master at MIP – School of Management Politecnico di Milano.
- May 2017 and April 2018, SBCE game in Barcelona at the Business School of the UPC (Universitat Politècnica de Catalunya)

Master of Science Lectures

- Since 2013 the game is used to teach Master of Science students during the Product Lifecycle Management Lecture for MSc students at Politecnico di Milano.
- January 2017, the SBCE game has been used to teach at a class in the Mechanical Department of Purdue University, USA.

Thanks to the high experience acquired by the authors, they participated and they have been invited to present and discuss SBCE Game in many national and international contexts directed to people from both industry and univeristy. Indeed, the SBCE Game is well

established also within the academic world with both conference presentations (and papers) and journal papers, such as:

- Kerga E., Taisch M., Terzi S., Rossi M. *Set Based Concurrent Engineering: Serious Gaming and Implications for Practice*. 19th International Conference on Engineering, Technology and Innovation (ICE), Responsible Innovation and Entrepreneurship . IEEE. The Netherlands June 24 – 26, 2013.
- Kerga, E., Akaberi, A., Tasich, M., Rossi, M., & Terzi, S. (2012). *Lean product development: Serious game and evaluation of the learning outcomes*. In *Advances in production management systems. Competitive manufacturing for innovative products and services* (pp. 590-597). Springer Berlin Heidelberg.
- Kerga, E., Rossi, M., Taisch, M., & Terzi, S. (2014). *A serious game for introducing set-based concurrent engineering in industrial practices*. *Concurrent Engineering*, 22(4), 333-346.
- Kerga, E., Rossi, M., Terzi, S., Taisch, M., Bessega, W., & Rosso, A. (2014). *Teaching set-based concurrent engineering to practitioners through gaming*. *International Journal of Product Development*, 19(5-6), 348-365.

But the most rewarding result is the appreciation of the real understanding the game provides to students. Attached slides resulting from SBCE game class in Politecnico di Milano during Product Lifecycle Management lecture (hold by Prof. Monica Rossi in 2017 and 2018). None of the learning has been explicitly told to the students but they, themselves, go through such lessons learned by playing the game. The final exams, that included a question on such learning, proved that the understanding of the topic is averagely high and higher than other topic explained with regular face to face lectures, as well as –of course- the understanding from people who did not attend the SBCE game session is drastically lower than the students who participated. Feedback from students on such way of teaching is being extraordinarily positive.

The SBCE Game first of all is a simulation of the SBCE process that occurs in a simplified and safe context, where players can experiment SBCE principles and enablers, without any risk for their organization. This is what makes serious games in general, and SBCE Game in the specific, so powerful. Not only SBCE Game is the first managerial and training game developed and officially licensed by Politecnico di Milano, but also it is the first SBCE Game ever, that's why Monica Rossi is asked to run many SBCE Game sessions/year at any different contexts.

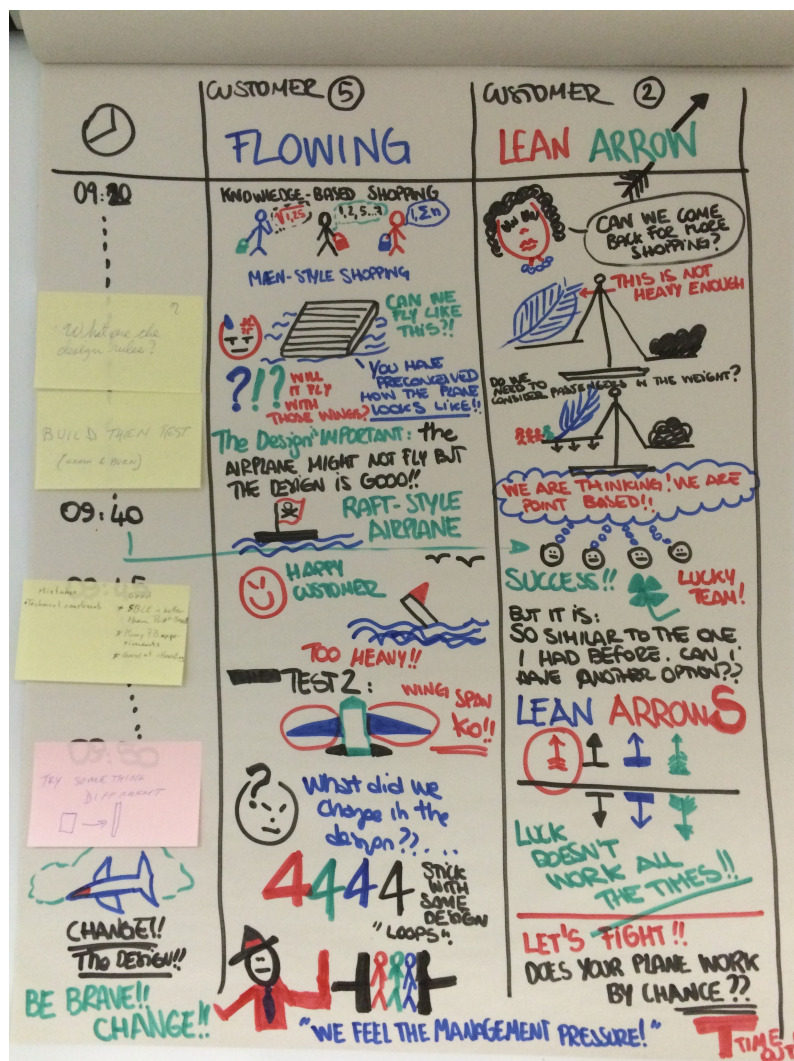
This makes the impact of the game as a learning tool extremely relevant. First of all the authors were able to publish academic contributions, both in conferences and journals, on SBCE and now their name are associated with this topic in literature. Main known personalities from the lean field (e.g. John Shook, James Morgan, Michael Kennedy, Durward Sobek) acknowledged the power of the SBCE game and not only invited the authors in more than an occasion to play and discuss about the game, but recognize the authors (and Politecnico di Milano) as one of the main experts in the topic.

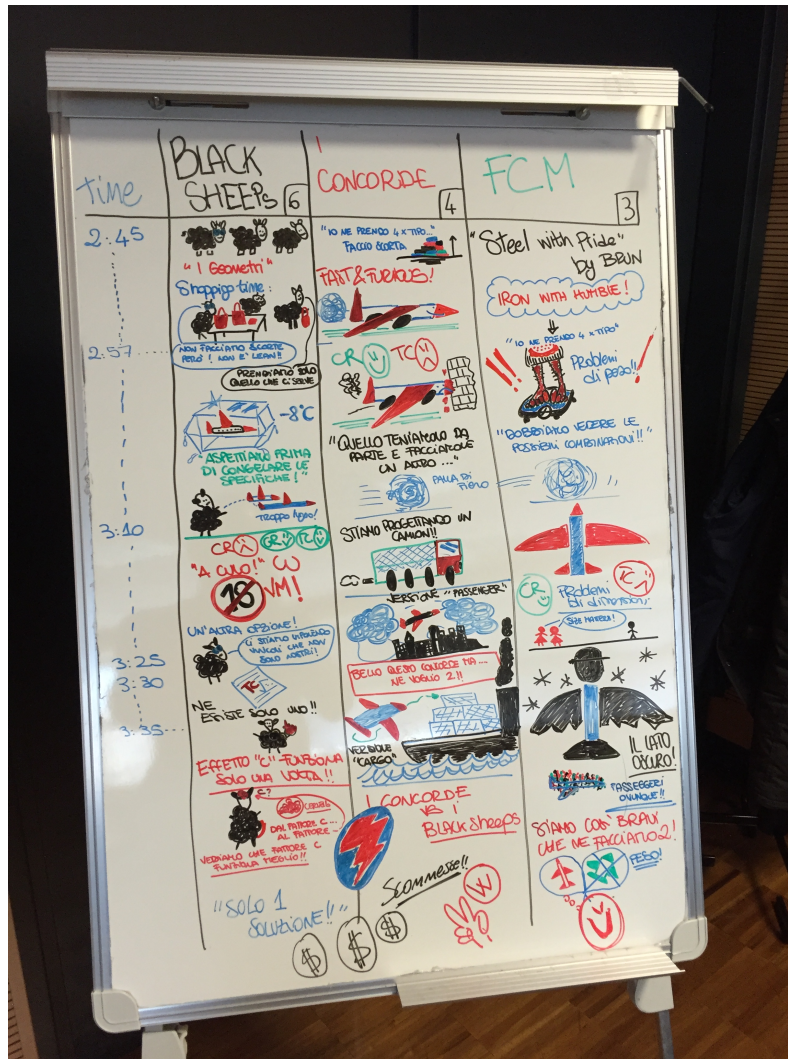
Also master students, graduate students and practitioners from SMEs and big enterprises all over the world (USA, Europe, Israel, Japan..) gained the benefit of learning the SBCE concept thanks to the SBCE Game. Authors (especially Monica) are now in the process of specialize themselves as facilitator of serious games as way of teaching and learning and are developing a curricula of serious games to teach real problems and real solutions based on proven theories to both students and practitioners while having fun!

The game got awarded as a finalist on the SOM Impact Prize 2015, initiative internally launched by Politecnico di Milano.

Teaching method and story telling.

One of the most unexpected yet effective results of teaching through SBCE game has been to develop facilitator skills to deliver the most beneficial learning experience. In the specific Monica has developed story telling technique that she uses during the game to graphically report real time behaviors, strategies and anecdotes of the teams. This becomes one strength in delivering the SBCE game session that fosters the ability within players to enhance the understanding of the learning objectives. In the following some examples of story telling drawn using game sessions and used to reinforce the learning.





Context and acknowledgments.

The SBCE Game is part of a bigger European Research Project, called LeanPPPD, run between 2009 and 2013. The objective of the project has been to define a lean product and process development model, able to bring to both university and industry a deeper understanding on lean product development dynamics and benefits. Also the project aimed at give practical insights on how lean product development could be applied within industry. Within the project, the team of researcher from Politecnico di Milano (in the specific Sergio Terzi, Monica Rossi and Endris Temam Kerga) was in charge of the training task. It is within this context that the researchers had chance to deeply get into the learning challenges of SBCE. Together with the Polimi team, different master students supported the research and helped the achievement of such outstanding result. The partners of the project supported Polimi team in the validation of the SBCE Game, that is now exclusively owned and licensed by Politecnico di Milano. Specially authors would like to acknowledge Endris Temam Kerga, PhD student on the topic while the game has been developed.

Links to conferences and workshop organized by different kind of institutions and organizations that invited the authors to run SBCE game session exist online, the authors are willing to provide those and any additional information required by the jury.