Full paper for SEFI 2016 Conference
Game of Robots, playful teaching for engineering students

Alexis Todoskoff
Responsible for collaboration between Enterprise partners and the ISTIA
LARIS, EA 7315, University of Angers - ISTIA, University of Angers
Angers, France
E-mail: alexis.todoskoff@univ-angers.fr

Laurent Bordet
Direction of Enterprise partners' collaboration
ISTIA, University of Angers
Angers, France
E-mail: laurent.bordet@univ-angers.fr

Chloé Dasse[1]
Academic Program Manager
ANSYS France
Montigny-le-Bretonneux, France
E-mail: chloe.dasse@ansys.com

Margarette Lim
Product Manager for BtoC
Expectra
Saint-Denis La Plaine Cedex, France
E-mail: margarette.lim@expectra.fr

Conference Key Areas: University-Business cooperation, Engineering Skills, Engineering Education

Keywords: Playful teaching, LEGO® Mindstorms robots, Robotics, SCADE

INTRODUCTION

For many years, the LEGO® Mindstorms robots [1] have been used as an educational tool to stimulate creativity, entrepreneurship, problem solving and teamwork, which are all aspects young graduates will encounter in their professional lives.

Like many other schools in France and worldwide [5, 6, 7, 8 *et al.*], ISTIA [2], the engineering school of the University of Angers (France), included Lego Mindstorms robots into its

[1] Chloé Dasse
chloe.dasse@ansys.com

engineering cursus. The idea arose after a visit to the Lego site in Billund [Denmark], and found inspiration in the challenges of the University of Oxford.

This Lego challenge was primarily used for first year engineering students' integration and group dynamics. ISTIA wanted to go further by including a second challenge in the curriculum of final year engineering students.

Focusing on the successful professional integration of these students, this second phase gathers the students in a playful yet educational spirit. It brings together two partners companies: the Systems Business Unit of ANSYS [3], leading provider of critical systems and software development solutions, and Expectra [4], a French leader in professional staffing and recruiting for managers, supervisors and engineers.

This challenge is thus a dual innovation:

- It associates partner companies not only during the event but also in the whole design cycle of the challenge (choice of the theme, organization of the week…) making the business aspect a full part of the pedagogy.
- It leveraged both tools and experience of these companies during the challenge with the SCADE platform of ANSYS for a workflow development down to the Lego Mindstorms robots, and with Expectra experience sharing for e-marketing and branding.

This article presents the organization and evaluation process of this educational event called "Game of Robots".

1 CONTEXT

1.1 General overview

Today, engineering sciences and techniques are rarely seen as attractive, particularly when they are directed to an industrial context. One cause is that engineering activities presented in an academic setting does not contain examples that are relevant to the current social interests of the students. Thus, this article provides a feedback on an attempt to "gamify" the learning of these sciences and their relative industry challenges.

The experience takes place at ISTIA (Advanced Institute of Science and Technology Engineering of Angers), the Engineering School of the University of Angers. The school trains engineers in various majors, including Industrial Systems Engineering, with three possible specializations: Automation and Computer Engineering, Quality and Dependability, Engineering of Innovation. When entering their last year of studies, students already have a technical background, each in their area of specialization.

This is when the challenge happens. Within mixed groups of five final-year students, the goal is to build a fully articulated robot able to move and react to its environment from precise specifications.

Fig. 1. A student calibrating his team's robot before the final

The interest of this experiment is mainly educational. It introduces students from different backgrounds to a complete engineering problem related to the reasoning they might encounter in an industrial setting.

ISTIA also uses this challenge to create an example of how important multidisciplinary areas are for the success of a project. Each team must find ways to work quickly and efficiently, using as best practices agile methods. Students can better understand the skills acquired from the various school majors and have in mind a uniform image of the school.

More than a competition, this challenge is an opportunity for students to use the knowledge acquired in their studies at the engineering school ISTIA. This is also the opportunity for ANSYS and Expectra to support an original educational initiative and reaffirm their commitment to innovation, training and upgrading courses for engineers. These shared commitments with ISTIA enabled an advanced industry-oriented pedagogical competition.

1.2 Ambitions and project objectives

Beyond the fun and friendly aspect, the entire event aims to expose students to project engineering over a short time period (one week).

Because the students have already participated in a Lego challenge during their first year at ISTIA, this event provides an opportunity to measure their progress on the acquisition of scientific and technical knowledge and in the understanding of the different facets of an engineering profession.

Indeed, this project is the conclusion of the lessons completed during their time at university. Eight courses were directly targeted and used: mechanics, computers, automation, organization, project management, agile conception, innovation, creativity, communication, and marketing. Therefore, taking into account all of these courses, the challenge highlights:

- The organization of a complete project:
    - Engineering approach (problem, context, method, solution, etc.)
    - Project management (requirements, organization, teamwork, limited time, V & V, etc.)
    - Work promotion and marketing (videos, social networks, etc.)
    - Creativity, information research and protection of innovations (through patents)
- The cohesion of the ISTIA engineers' mind-set:

- Multidisciplinary / team diversity (transversal skills)
- Valuation and understanding of the ISTIA majors
- The sense of belonging to the school

2 THE ORGANIZATION PHASE

2.1 Project team

One of the essential prerequisites for this type of project is obtaining the agreement and the effective involvement of the school administration.

The pedagogic team must be ready to invest fully. The upstream preparatory work is substantial: determine a challenge topic that is both educationally and industrially interesting, test and validate this idea, develop strict specifications (to give chances to everyone) but leaving a multitude of possible technological choices (so that participants do not all end up with the same design), plus organize the logistics of the event. The work during the challenge week is also important because the supervising team must be available to coach, mentor, advise and evaluate students.

The timetable of professors must be set up; project rooms, labs and computers must be released; specific software must be installed. Finally, the material should be made available in sufficient numbers.

On the other hand, the industrial partners' team with ANSYS and Expectra provides business and industrial means to ensure proximity to market needs, to widely publicize the event and to maintain a high technical level of expertise.

A two-monthly meetings 6-months ahead of the challenge were required within a team comprised of:

- ISTIA: 5 people of the External Relations Department + 1 Engineer. In addition, each major leader was present at the challenge as arbitrator,
- ANSYS: 1 Academic Program Manager, 1 Engineer, 1 Marketing Manager,
- Expectra: 1 Digital Marketing Division Manager, 1 BtoC Product Manager, 1 Web Project Marketing Manager.

2.2 Calendar

The organization begins by:

- The choice of the environment: very quickly, the organization team agreed on a Star Wars universe to piggyback on the success of the film's release in December 2015.
- The rules and play areas have been quickly defined based on that theme, to balance simplicity and visual impact, especially for spectators and referees.

The challenge was presented to students three months ahead. They created teams of five, mixing all majors (one to two students from each major). They were asked to:

- Define their identity: name, crest and motto,
- Create two videos (30 seconds to 1 minute) to present the team and robots,
- Set up their marketing strategy,
- Attribute roles within the team: one project manager, one SCRUM responsible for managing agile methods criteria, one Industrial Property responsible in charge of drafting patents and perform ensued strategic alliances, two robots' managers and one marketing manager.

They had one month to meet and work on their identity.

At the closing of the annual ISTIA school-companies' forum, two months ahead of the challenge, each team presented itself in front of a panel of ISTIA teachers, ANSYS and Expectra delegates. After this presentation, their videos were centralized on the event YouTube channel, which represented the start of the marketing and communication side of the competition. The biggest social impact, the more points awarded.

At the same time, the organization team released a website with a blog containing all the necessary resources for the students to carry on their challenge.

One month ahead the challenge, each team was trained on the ANSYS SCADE modelling environment. This tool was one of the requirements the students had to fulfil when programming their robots. ANSYS SCADE is a formal, comprehensive, industry-proven solution for developing systems and software, supporting the entire development workflow, from requirements analysis and design through verification, implementation, and deployment.

Within the internal website, the participants had access to self-learning videos complementing the two-day training provided by an ANSYS consultant as part of the usual curriculum.

Additionally, the participants completed two practical exercises based on the challenge specifications. The exercises helped them to get started on modelling, simulation and code generation.

In the meanwhile, the organization team was working on:

- The purchase of goodies, tee-shirts, caps, and prizes for the winners,
- The creation of banners,
- The film crew to conduct interviews,
- The mobilization of audio-visual services of the University of Angers for live capture and web broadcast on social networks.

2.3 Material used

The material used for this project is the LEGO® Mindstorms NXT education package. This material has been chosen for its fast learning curve and its robustness. It comprises:

- Simple mechanical elements, easily interconnected, that most students have already rubbed,
- Sensors and actuators, reliable, and simple to configure,
- A control brick that can be programmed very simply, but capable of handling sophisticated programs.

Each team has 2 Lego boxes composed of:

- 3 actuators,
- 1 light sensor,
- 1 sound sensor,
- 1 ultrasonic distance sensor,
- 2 contact sensors,
- 1 gyro sensor,
- 1 battery and 6 LR6 battery (AA) by robot,
- Link and assembly parts.

Fig. 2. Lego Mindstorms Sensors and actuators

2.4 Aim

The challenge aimed at creating an autonomous robot performing one trajectory loop counter-clockwise and crossing four obstacles:

- Sand dunes materialized with a wave form foam,
- Speed bumps made of wooden brackets,
- Left-Right avoidance obstacles,
- A death jump with a ramp ending with a vertical drop.

Additional points were granted to drop down two Dark Vadors from their towers.

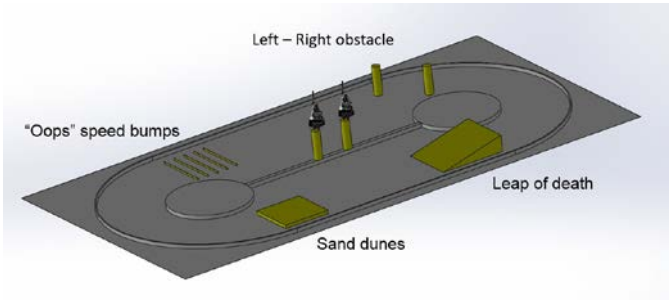

Fig. 3. The playground based on the Star Wars Universe

When starting, the robots were placed randomly by the jury, each at one side of the tray. They had to start with only pressing the pressure sensor and stop after having completely crossed the finish line.

2.5 Playground and robots' specifications

2.5.1 The playground

The circuit was done in wood, and composed of a tray delimited by a slide.
All obstacles and actions were identified before and after by a colour code. The robots had to go through all of them following an ideal black line.

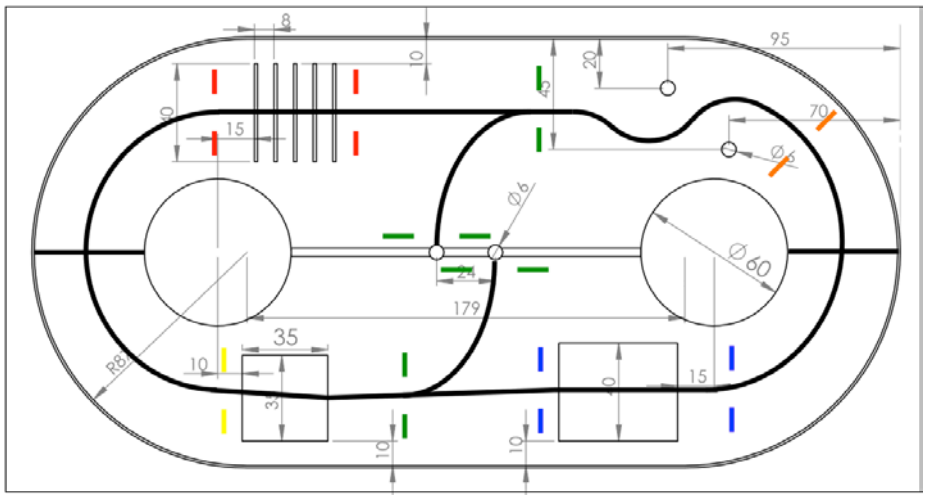

Fig. 4. The playground based on the Star Wars Universe

2.5.2 The robots

The robot had to comply with the following dimensions at the start and finish lines:

- Length <29.7 cm
- Width <21 cm
- Height <20 cm

These dimensions could change during the race to overcome the obstacles or to take down the Dark Vadors from their towers for example.

2.6 Statement and rules

For the whole organization of the challenge, an internal website with a blog has been developed for:

- A general presentation of the challenge,
- The specifications,
- Tutorials on software installation, use and embedding (nxtOSEK, SCADE),
- Exercises based including from functional requirements to the automatic generation of code on the robot to prepare the robots' programming,
- How to create technological patents for the challenge,
- The schedule and deadlines.

2.6.1 Hardware

They have been required to use LEGO Mindstorms. The reason is that this technology avoids situations often encountered where students are facing technical difficulties with basic implementation. The reliance on already functional modules allows to go faster and further in the design.

Furthermore, if the system created does not work, students challenge themselves first before accusing the hardware. LEGO are robust and reliable: students learn very fast how to use it and how to embed code in it.

2.6.2 Software

The students have been required to grasp the formal high-level language specification used in the industry through the ANSYS SCADE tools. This formal specification language allowed in particular to verify, simulate and automatically generate code

before downloading it to the LEGO brick. They used the nxtOSEK environment to integrate and embed the code.

The primary objective was to expose students to rigor and industry tools. The learning of this language is already part of their curriculum. ISTIA to focus on it so that students can feel its benefit in a scalable project.

Naturally, students tended to structure their own program. A difficulty that the organization team had not anticipated is the management of multitasking. Most teams have used this solution. The students, who have no knowledge of the peculiarities of concurrent programming, have developed programs with non-deterministic operation. This is a point that the organization team will clarify for the next challenge.

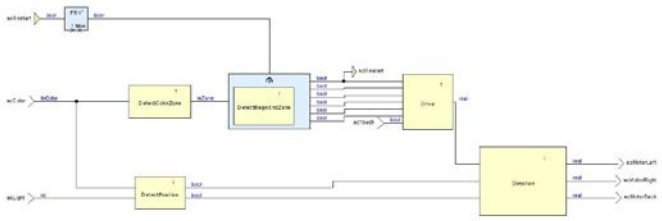

Fig. 5. Program developed with ANSYS SCADE Suite

3 THE CHALLENGE PHASE

3.1 Organization

The challenge took place over an entire week. Students were divided in teams of 5 people.

- Monday was about reminders of ANSYS SCADE environment, delivery of robots' specifications and challenge rules.
- Mondays, Tuesdays and Wednesdays were for design, build and program the robot. They are complemented by ANSYS SCADE tutoring.
- Tuesday and Wednesday were dedicated to patents hand-over.
- Thursday was dedicated to the last programing settings.
- Friday was reserved for the competition with the qualifying stages (morning) and finals (afternoon)

	Day 1	Day 2	Day 3	Day 4	Day 5
8h00	Statement of work handover	Questions exercise	Patents submission		Calibration
9h00	Patents preparation SCADE and Lego training Conception	Patents submission SCADE tutoring Conception	Conception	Robots videos Conception	Qualification
12h00			Patents publication	Conception End of trial before competition End of marketing activities	Calibration
14h00		Conception 1st qualification: trajectory following Exercise answers Patents submission SCADE tutoring	Conception 2nd qualification: Leap of death		Finale
16h30					Prizes handover
17h30	Goodies handover	Debriefing	Debriefing		

Fig. 6. Event organization calendar

3.2 The games

Each game pits two teams against each other. Each game includes two loops starting each at the opposed sides of the tray.

The first team to complete the tour wins the match. If none of them can do so, each obstacle overcome brings points based on its difficulty. The team winning the most points over the two loops wins the game. Points are awarded if the robot successfully:

- Passes the sand dunes along their entire length: 1 point,
- Passes the 5 speed bumps: 1 point,
- Passes the left-right obstacle: 1 point,
- Passes the death jump completely: 1 point,
- Kills its own Dark Vador: 2 points,
- Kills the Dark Vador of the opponent: 1 point,
- Ends the loop, passes the finish line and stops: 2 points,
- Reaches the opponent: 2 points.

3.2.1 Qualification phases

During the morning, three rounds of qualifying phases through two groups of six teams take place, so each team performs five games. A won game gives 4 points, a tie game 2 points and 1 point for defeat. Equality is accepted.

Additional points are awarded for fulfilment of requirements. For example, quality designs done with ANSYS SCADE awarded 3 additional points.

3.2.2 Final phases

The top 8 teams of the qualification rounds competed in a knockout tournament (quarterfinals, semi-finals, losers' final, and winners' final). The games were chosen taking into account the benefit of the qualification rounds in a way that the two best teams of the qualification rounds were not competing on the first games.

There is only one winner of each game. If neither team has scored, then the jury declares as winner the robot found most ingenious.

3.3 Ascertainment

On the technical side, for all teams, before embarking on the construction of the robot, students have all spent time thinking about the best strategy to win the competition. They ended up with numerous technical solutions, strategies and designs: wheels or tracks, different sizes of wheels, axles... More surprisingly, the robots have evolved between the qualification phases, where the results were uncertain, and the finals. Indeed, they were allowed design and implementation changes anytime.

On the pedagogical side, the challenge allowed students to gather around an educational event fostering a federative group dynamic.

The cohesion of the teams from different backgrounds and the upstream challenges allowed the students not only to participate in the communication of the event but also to disseminate the associated values. This is evidenced by the interactions on the web throughout the operation (videos' virality, e-reputation and digital identity of the teams…).

Beyond the educational aspect, the students push forward the ability of being challenged by two companies, as an image of what they will face in their professional life a few months after the challenge.

The return from the students is therefore very positive, the atmosphere of the final being the best proof. The students willingly answered to requests from various local media and event partners. Aware that they are the best ambassadors for the event, they also value their training, passport to their future employability.

4 RESULTS AND BALANCE

4.1 Balance

This experience is highly rewarding on many aspects. Indisputably, the scenario around a common project was very well received by students (about 90% of satisfied or very satisfied).

They have all appreciated the difficulties of implementing a mechatronic product. They realized that the mechanical parts, automatic programming, and strategy, influence all each other, and that a failure of one of these elements leads to a flawed and inconsistent product in regards with the expected functions. The discovery of engineering problems related to the design, implementation, testing and operation of a product, is a perfectly fulfilled objective.

An equally important point is the group cohesion, and the spirit of promotion that the challenge fostered.

One of the greatest satisfactions of the challenge is that from the same specifications, the teams were able to show great creativity. There was very little resemblance both for the mechanical, programming and communications strategies with a wide variety of different approaches.

4.2 School – companies' collaboration

The challenge enables new types of collaboration. It goes beyond the simple relationship through the training / employment and apprenticeship tax applying in the relationship school / business with methods of open innovation and co-creation.

On this project, the collaboration:

- Ensures that the project meets the expectations of young graduates,
- Ensures a balance between the educational objectives and "playful" goals,
- Increases communication around the event by touching both institutional and private targets,
- Creates buzz directly with students talking to students (Facebook, Twitter, YouTube, campaign 100% user generated content, at zero cost to the brands)
- Moves from a "marketing push "to a "marketing pull ", with easy and impacting viral content to power speaking out on social networks,
- Reduces costs and varies the sources of financing,
- Shows that this type of partnership is by nature a source of innovation.

4.2.1 Expectra, Sourcing Company

For Expectra, the association with ISTIA allowed to answering the objectives of:

- Company's brand image improvement,
- Sourcing of business-demanded profiles: very early, with future candidates with great skills (capacity for teamwork, project management, motivation, sense of innovation, leadership ...),
- Mobilization of domestic employees, proud to organize this type of event,
- Pre-emption of territory of brand expression (innovation, competition, fun) face of competing companies,
- Providing further evidence for tendering (evidence of sourcing initiatives with respect to young graduates, as well as ability to innovate and use social networks),
- Adequacy of brand communication to the graduate with ground realities.

The experience of ISTIA in engineering and teaching innovation has helped frame the project from a technical point of view. The contribution of Expectra marketing teams has generated a wealth of quality content that is extremely difficult for a school to achieve. In this respect the media exposure of Expectra is an undeniable awareness increase for ISTIA.

4.2.2 ANSYS, Software Provider Company

Over the last few years, ANSYS has totally reorganized its activities for the ANSYS SCADE academic market. The company now has a dedicated service for working at supporting the initiatives from the registered participants of the academic program.

ISTIA is a long-term partner of ANSYS. By supporting the Game of Robots challenge, ANSYS wanted to show case one example of a project implemented jointly with one of the ANSYS SCADE users.

Based on the experience gained from the challenge, ANSYS released a teaching package on Lego made available to all professors registered for the event. This package included all technical material, as well as some tips to implement robotics activities with Lego.

The academic program for ANSYS SCADE is currently open to schools, and their professors. It now moves towards students. This challenge was one opportunity to get closer to this category of software user, assess needs, and guidance that would be necessary when opened to students.

Finally, as ANSYS benefits from an extensive industrial experience, the final goal was to make sure students face a professional environment even through a ludic challenge.

4.3 Perspectives

Overall, this challenge is a success even if improvements are considered:

- The internal dynamics in ISTIA needs to be strengthened. The challenge leader will promote the event internally to get more support from the major leaders.
- The project will also be tested beforehand by a secret team of students to validate the feasibility and possible deviations.
- From a student perspective, as the challenge was not compulsory, the engagement within the team was varying. ISTIA has thus decided to integrate it into the students' curriculum.
- The organization team will also integrate into the challenge rules stating that the purchases of views and 'like' on social networks is prohibited.

The positive elements include:

- The heterogeneity of teams that made students feel what project engineering and team work means. They learnt how to leverage multi-skills.
- Teams were committed to be the best. The positive atmosphere attracted 4th year students to already start thinking about the next challenge.
- The buzz and media coverage of the event, with four press organizations has increased all partners' branding. The challenge is successful and has further anchored ISTIA, ANSYS and Expectra as partners for innovative engineers in higher education courses.

Fig. 7. Cohesion spirit of Game of Robots

REFERENCES

[1] https://education.lego.com/en-au/lego-education-product-database/mindstorms/9797-lego-mindstorms-education-base-set

[2] http://www.istia.univ-angers.fr/fr/index.html

[3] http://www.esterel-technologies.com

[4] http://www.expectra.fr/

[5] Lawhead, P. B., M. E. Duncan, C. G. Bland, M. Goldweber, M. Schep, D. J. Barnes, et R. G. Hollingsworth. « A road map for teaching introductory programming using LEGO Mindstorms robots ». In Proceedings of the Conference on Integrating Technology into Computer Science Education, ITiCSE, 191‑201, 2002.

[6] Karp, T. « Teaching a service learning introductory engineering course - Lessons learned and improvements made ». In Proceedings - Frontiers in Education Conference, FIE, 2011.

[7] Apiola, M., M. Lattu, et T. A. Pasanen. « Creativity-supporting learning environment-CSLE ». ACM Transactions on Computing Education 12, no 3 (2012).

[8] McWhorter, W. I., et B. C. O'Connor. « Do LEGO Mindstorms motivate students in CS1? » In SIGCSE'09 - Proceedings of the 40th ACM Technical Symposium on Computer Science Education, 438‑ 42, 2009.