Development of innovative suspensions for a radio-controlled light racing car
Collaborative project into 3DExperience platform

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INTRODUCTION

Engineering Schools currently face the challenge to train their students for the forthcoming Industry 4.0. There is no clear definition about Industry 4.0; however, it is clear that Industry 4.0 companies will be connected through data over the Internet.

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Engineering data in industry exhibits two features which are difficult to convey in engineering education: 1) the data generated by the different apps has intrinsic dependencies and 2) it is iterative. Thus, the geometry designed in CAD apps is analysed for performance with CAE apps and manufactured with CAM apps. Likewise, if the tasks performed with CAE and CAM apps assess CAD data as invalid, CAD data has to be reworked. Consequently, CAE and CAM tasks might have to be reworked. Therefore, keeping track of the data version over which engineers are working becomes critical in industry and it is addressed with PLM platforms. Furthermore, in engineering practice, globalization and customer-supplier relationships impose the collaborative generation of such data in geographically worldwide distributed teams. This need to collaborate adds extra features that are difficult to convey in engineering education such as geographic location difference, time-zone difference, calendar difference, timetable difference, language difference and cultural habit difference among team members' management.

Project Based Learning (PBL henceforth) activities have shown to be effective in teaching the interdependencies between the different engineering domains (design, analysis, manufacturing, etc.). The advantage with this innovative methodology of learning is that there is close relationship with real-life requirements and collaborative industry working methods. What is more, this connection between real-life problems, teaching and collaborative industry working methods makes students' motivation increase, which simultaneously makes knowledge exciting and learning enjoyable; the straightforward consequence is a deeper learning than with traditional approaches. Since 2011, all university programs at the Faculty of Engineering of Mondragon Unibertsitatea have formally assumed PBL as their cornerstone, both for teaching and learning [1,2]; in the same way, the Institute of Technology of University of Nantes is using industrial projects in learning and collaborative interdisciplinary PBL since 2007 for mechanical design and manufacturing collaborative learning for bachelor students.

However, data version management and the natural time limits of engineering curricula constrain the amount of iterations that can be performed in PBL activities. On the other hand, within a single university and a single course, it is difficult to reproduce the collaboration constrains globalization imposed on engineering practice such as geographic separation, time-zone, calendar, timetable, language and cultural habit difference management among team members.

3DExperience on Cloud is a novel and the first software platform on Cloud that integrates the multidisciplinary apps required by engineers:

- CAD: next version after CATIA V6
- CAM: next version of Delmia
- CAE: next versions of ABAQUS, XFlow, Dymola and iSight
- PLM: next version of Enovia

In addition, its social communities engage engineers with non-engineering disciplines and its Dashboards provide fast web access in order to fully review and perform minor edits on the heavy engineering data. In contrast to their desktop counterparts,

3DExperience apps are connected to the Internet and directly store the engineering data objects generated by its apps on the 3DExperience PLM server on Cloud. Thus, 3DExperience on Cloud is an enhanced PLM solution that can help engineering schools in teaching the iterative nature and dependencies among engineering data to students. Furthermore, as it is connected to the Cloud, it enables setting-up collaborative inter-university PBL activities to reproduce the collaborativᵒe industrial engineering practices imposed by globalization [3,4].

Therefore, Institute of Technology of University of Nantes and the Faculty of Engineering of Mondragon Unibertsitatea have set-up a PBL activity to research whether using 3DExperience on Cloud can be helpful in integrating these Industry 4.0 engineering practice features into the PBL learning experiences of their students. Both universities aim to improve the employability of their students by the forthcoming Industry 4.0 with the inclusion of such features in their learning experiences.

Moreover, as 3DExperience on Cloud is new and the first software platform of this kind, in contrast to what happens with the desktop counterparts of its individual domain apps, there are very few public resources to assist students in the learning process. Therefore, the main learning resource is its users' guide and the integrated Peer Learning Experience platform, where Dassault Systèmes and a worldwide community of university lecturers publish peer reviewed learning materials about all apps available in 3DExperience on Cloud. However, as there are so many courses within Peer Learning Experience, free course selection by students was identified as a risk for project deliverables and another research question arose. Is it possible to define an autonomous student learning path with Peer Learning Experiences courses?

1 METHODOLOGY

In order to test 3DExperience on Cloud's helpfulness to integrate the Industry 4.0 engineering practice features into a PBL learning experience, Mondragon Unibertsitatea and University of Nantes had to set-up a novel type of PBL. Thus, a decision to make their students collaborate in their regular PBL over 3DExperience on Cloud was made.

1.1 PBL Planning: Buri Racer

The PBL chosen had to be motivating in order to ensure that conclusions are only related to the helpfulness of 3DExperience on Cloud. No doubt, cars are very attractive products to design in the engineering field. Due to that, the chosen product to develop the project is an on-road 8th scale radio-controlled electric four-wheel drive racing "pancar", a new very fast and effective category of radio-controlled racing car, which was born last years with the arrival of the Buri Racer E1 developed by the teacher from Austria Thomas Burger-Ringer [5]. It is a "pancar" type of vehicle with no springs/dampers on its suspensions, only material deformation. This type of car is very light and the transmission is more effective, but the design of the flexible parts is critical for the handling; the car is shown in *Fig. 1* and *Fig. 2*.
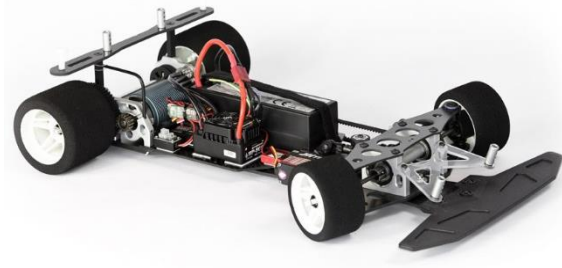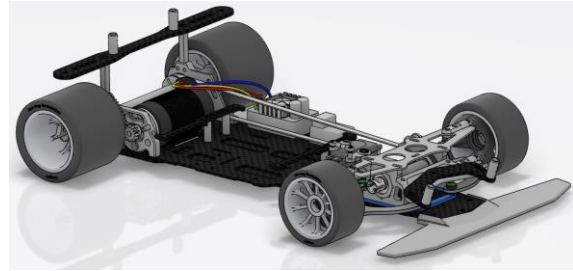
Fig. 1. Buri Racer car [5].

Fig. 2. Initial CAD of the car.

While Nantes team was working on the mechanical design of the rear and front suspensions of the car, Mondragon team was working on the finite element analysis of the car to optimise its design. The teams are shown in *Fig. 3* and *Fig. 4*.

Fig. 3. Nantes team.

Fig. 4. Mondragon team.

One of the technical challenges of the project was the development of flexible parts to work as a suspension system, since usually these kinds of radio-controlled "pancar" cars do not have suspensions at all or springs between chassis parts. Those flexible parts are shown in *Fig. 5* and *Fig. 6*.

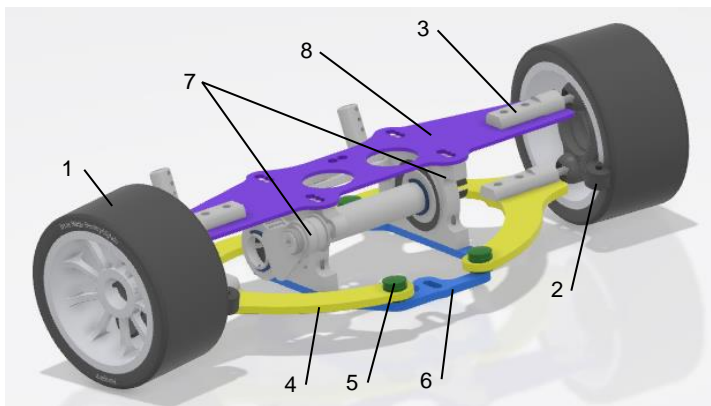### 1.2 PBL Planning: Tested industry 4.0 Engineering Practices

Under these conditions, students were involved in a scenario where the two most fundamental Industry 4.0 engineering practice features were present:

- **Geographical location difference**: Mondragon and Nantes are 650 km far from each other.
- **Data version management**: Nantes students create and iterate over design CAD data, and Mondragon students create performance analysis CAE data that depend on CAD data.

In addition, students would have to manage language difference, as the mother tongue of Nantes students is French, and Spanish and/or Basque for Mondragon students. However, in order to handle this difference collaboration happened in English.
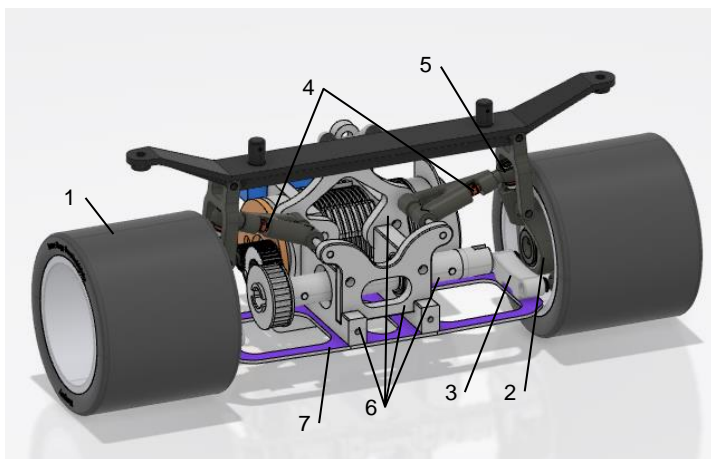
Due to the nature of collaborating universities and student groups other Industry 4.0 engineering practice features, namely, cultural habit difference and time-zone difference management skills were considered not to bias this work.

However, as teams had different calendars and timetables, students had to manage them in some extent. These may have generated some bias on the conclusions.

1. Wheels & rims
2. Knuckles
3. Vice
4. Trapezium
5. Ball-joints
6. Chassis
7. Chassis
8. Flexible part

Fig. 5. Front suspension, flexible part in purple.

1. Wheels & rims
2. Knuckles
3. Vice
4. Upper triangle
5. Ball-joints
6. Chassis
7. Flexible part

Fig. 6. Rear suspension, flexible part in purple.

Project kick-off meeting was on November 10. Before that time, Nantes and Mondragon lecturers had been working on project details and specifications while Nantes students had been working on an initial design of the whole car, as shown in *Fig. 1* and *Fig. 2*. Project finished on February 20.

1.3 PBL Planning: 3DExperience on Cloud Learning Path

Learning path for Nantes and Mondragon students was different because they were going to perform different activities and they had different background knowledge about similar desktop applications.

Nantes students already had previous knowledge about CAD in desktop applications such as SolidWorks and CATIA V5. Therefore, they mainly had to adapt to 3DExperience as a platform and map their previous knowledge to 3DExperience design apps.

Mondragon students had previous knowledge about CAD in SolidWorks, but in-depth desktop CAE application learning had to happen at the same time as learning the 3DExperience on Cloud CAE app.

Thus, in order to support students in their 3DExperience on Cloud learning curve, the following Peer Learning Experience learning path with an estimated duration of 53 hours was designed by lecturers to get the basic 3DExperience and CAD/CAE skills:

1. Gateway to 3DEXPERIENCE
2. CATIA Part Design Fundamentals
3. CATIA Assembly Design Fundamentals
4. SIMULIA Structural Model Creation Essentials
5. SIMULIA Structural Scenario Creation Essentials
6. SIMULIA Composites Simulation Engineer Essentials
7. SIMULIA Structural Model Creation : Geometry and Meshing

1.4 PBL Planning: Relevant 3DExperience Features

3DExperience on Cloud integrates many regular CAD/CAE tools with a PLM and additional features. However, only those relevant features that are different to their counterpart desktop apps are briefly described next.

In particular, in order to handle data version management, the underlying PLM platform (former Enovia, now Collaborative Lifecycle) was the database where all engineering data was stored every time. This helped students keep track of the latest version. In addition, as now CAD and CAE tools are integrated, the CAD data used by Mondragon students to start with CAE analysis tasks was an Abstraction of the original CAD data generated by Nantes students. Abstractions are an important collaborative workflow feature, because they create linked copies of the bodies in an assembly. This enable CAE analysts to decide when they want to get the latest CAD data in their CAE environment by unlinking or relinking the copied bodies.

Additionally to the PLM features, another remarkable feature is 3DMessaging. Initially it looks like a simple text chat feature between users logged-in to 3DExperience on Cloud who decide to be available for communication through 3DMessaging. However, it also has videoconferencing capabilities. Furthermore, through its Co-Review button, it enables a live design review feature that synchronizes the 3D views of the CAD data of the users taking part in the meeting, along with making 2D text and curve annotations over the 3D data and storing such views as snapshots. Finally, it also has a Design Share feature, which enables members of the meeting to submit live design feature changes, committed on Nantes to Mondragon and vice versa, without saving the data.

2   PBL EXECUTION: THE EXPERIENCE

Collaboration in CAD and simulation could be either simultaneous or sequential. First, Nantes team made an initial design and wrote the requirements for the simulation objectives. The 3DExperience software could be used for requirements management

in the RFLP applications (Requirements, Function, Logical and Physical Design) to relate directly the 3D model and the requirement.

To create the initial model, Nantes students worked in a simultaneous collaboration (everyone on the same 3D assembly at the same time), as shown in *Fig. 7*.

Fig. 7. Simultaneous collaborative work on 3D model (Nantes).

Mondragon students, connected to the same database, could then open the models and realize their first simulations to assure that the requirements where well understood.

Distant collaboration was then sequentially achieved, with review meetings of two types: classical videoconference and direct review application in 3DExperience, as shown in *Fig. 8*. The last one is again possible because students access the same database and therefore no files exchanges or distant screen sharing is needed.

Fig. 8. Videoconference meeting and direct review application in 3DExperience.

The workflow introduced in 3DExperience for the numerical simulation is a great enhancement in the industrial framework. A new concept of "representation" of the 3D parts insures the traceability and the updating of the numerical simulations when a part is modified; with this new method, a design team and a simulation team can work at the same time on the same parts.

Planning of tasks was done in the platform too; this enabled students to share all the information at the same place: the 3DExperience dashboard of the project.

At the end, Mondragon team proposed material selections and design concepts to the mechanical designers, which resulted in the manufacturing of the prototype by Nantes team. Final prototype is shown in *Fig. 9.*

Fig. 9. Carbon fiber prototype with special orientations and a 3D-printed suspension part with nylon honeycomb and fiberglass-fibers (Markforged printer).

3   RESULTS

Once the PBL was over, three surveys were passed on both universities (at each university on their mother tongue):

1. A survey to assess the helpfulness of 3DExperience on Cloud to obtain Industry 4.0 industrial engineering practices was given to students.
2. A survey to assess the usefulness of the proposed Peer Learning Experience learning path was passed to students.
3. A survey to assess the helpfulness of 3DExperience on Cloud to obtain Industry 4.0 industrial engineering practices was given to lecturers.

3.1 3DExperience helpfulness for students

Most of Mondragon students considered that the 3DExperience platform facilitated the collaboration and communication between them and Nantes students; furthermore, they appreciated it as an enriching experience close to the industrial reality.

Nantes students greatly appreciated especially the native simultaneous mechanical design collaboration. The Co-Review app was considered as an improvement for understanding the requirements in comparison with the videoconference meetings. They had troubles with the project management since there was not a team leader of the project, a point on which we have to improve for future projects.

3.2 Peer Learning Experience learning path

Mondragon students regarded the learning path as improvable and they consider that the tutorials are not clear enough considering their previous knowledge about the platform. They suggested enriching the tutorials with real examples for future new users. At the very beginning, the learning curve is very steep and students confirm that it took them two months to go ahead and understand the 3DExperience platform's working philosophy.

Nantes students already knew SolidWorks and CATIA V5; therefore, their learning process was very short (3 hours per course) for the mechanical collaborative design and no more courses were needed on this subject. They appreciated the user interface of 3DExperience and the database file system, even though at the start a transition period was needed. However, regarding the workflow applications such as project dashboard, planning and workflow, the students did not feel confident enough to use them. This was not expected since these applications are easy to use compared to the high-tech design apps. It shows that the students consider the collaborative work not in their scope compared to the mechanical design skills.

3.3 3DExperience helpfulness for lecturers

Both Mondragon and Nantes lecturers regard 3DExperience on Cloud platform is suitable for PBL supervision and highly effective for creating external collaborative projects like this one.

4 SUMMARY AND CONCLUSIONS

In conclusion, the Institute of Technology of University of Nantes and the Faculty of Engineering of Mondragon Unibertsitatea have found 3DExperience on Cloud appropriate to teach engineering students the Industry 4.0 engineering practice features of engineering data version management and different geographical location.

Additionally, the learning path designed based on the Peer Learning Experience has been found to be useful but improvable with more realistic use cases.

5 ACKNOWLEDGMENTS

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