

# IMPLEMENTING CDIO APPROACH IN INTEGRATED DIGITAL ENVIRONMENT

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## ABSTRACT

For university students, internships in industry are opportunity to apply concepts learned in their academics and develop their soft skills required to work in an interdisciplinary team of professionals. Internship projects can be implemented over a short duration or long duration, which often decides the insight and experience gained by students during that period. In order to maximise this gain, students need to be efficient in learning pre-requisites, planning and execution of the project.

This work focuses on application of CDIO approach in an integrated digital environment, for implementation and progression of such projects. The projects in an industry environment are often target oriented and require students to learn/practice new skills required for their project. It is a lifelong learning process, as in industry engineers have to work on new projects requiring new skills and collaborate with professionals from different background.

We present an implementation of a new usage-scenario for *Virtual Twin project* at Learning Lab in Global Academia, Dassault Systèmes. *Virtual twin project* is implementation of open source humanoid robot – ‘Poppy humanoid’, using 3DEXPERIENCE platform. The usage scenario discussed, focusses on basics of machine learning and mechatronics for Poppy humanoid robot. The CDIO concept is applied in forms of - *inspire, learn, innovate, create* and *evaluate* activities - using combination of different 3D systems and digital platform. This work shows how to effectively evolve an advanced project for students and their supervisors over a short duration, using CDIO methodology and an integrated digital platforms.

## KEYWORDS

Project based learning, Project management, Life-long learning, CDIO Standards, e.g., Standards: 1, 3, 6, 7, 8, and 11

## BACKGROUND

Project centric learning approach is one of the prominent methods being implemented in academics and industry, for the university students to gain practical experience. It provides an environment for students to have better understanding of a subject through active exploration of some realistic problems around them. Universities are promoting this approach by including project based learning as a regular part of their course curriculum.

Industrial environment provides such opportunity for students to learn, apply and gain hands on experience through projects. This is normally in form of internships, co-op, practicum or

apprenticeships (Hora, Wolfgram, & Thompson, 2017). Internships provides opportunity for students to work with professional employers where they can ideally apply their academic learning to real-world problems (Hora et al., 2017). This makes it important to implement projects effectively, so both students and employers gain positive experience from the activity. The projects implemented in such an environment may have following characteristics deciding its effectiveness: coordination between academic and jobsite roles, duration, autonomy, task clarity, frequency, feedback mechanisms for the students etc. They can be implemented over a short duration or long duration, which often decides the insight and experience gained by students, during the implementation period. During the period of execution, students have to learn and adapt to new requirements to be efficient in learning pre-requisites, planning and execution, at different stages of the project. In order to contribute constructively, in complex engineering projects students should be able to *Conceive--Design--Implement--Operate* complex value-added engineering products and systems in modern team-based environments, as stated in CDIO Standard 1.

In professional environment, projects are conducted among teams with different backgrounds and are time bound. This makes ability to learn and adapt in short amount of time important. While working on technically advanced projects, requiring multi-disciplinary skills, students may face difficulty in defining targets and communicating within and outside the team, as the working environment being different from academics. It needs to be like a lifelong learning process, as in industry engineers have to work on new projects requiring new skills and collaborate with professionals from different background on a regular basis. As a result, integrated learning experiences which support gaining of technical skills with interpersonal, social and interaction skills are required. CDIO standard 7 also, emphasises this point.

In this work we discuss implementing an interdisciplinary complex project in an integrated digital environment (IDE). We discuss how to effectively evolve an advanced project for students and their supervisors over a short duration, using CDIO methodology and new digital platforms. The implementation scenario discussed here, has been implemented over a period of three months and is a part of existing project, where acquiring of knowledge of the work previously done is the first priority.

## **IMPLEMENTATION METHODOLOGY**

### ***CDIO applicability***

The CDIO Initiative is an educational framework stressing engineering fundamentals set in the context of conceiving, designing, implementing and operating real-world systems and products. As per CDIO revised syllabus, consisting of following parts - disciplinary knowledge and reasoning, personal and professional skills and attributes, interpersonal skills: teamwork and communication and conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context (Crawley, 2011) – it can address the difficulties for effectively implementing advanced interdisciplinary projects in industry, for university students.

CDIO's standards 1, 3, 6, 7, 8 and 11 address the requirements like interdisciplinary skills, learning ability, adapting ability, communication skill, proposal and target definition skill, and assessment skills – which can help to implement projects on IDE. CDIO's standard 7, 8 - Integrated Learning Experiences and Active Learning – should make IDE an interactive learning platform.

## ILICE – implementation framework

In order to implement CDIO approach on IDE project we propose using - *inspire, learn, innovate, create* and *evaluate* (ILICE) activities. These activities are proposed to implement *conceive, design, implement* and *operate* at different phases in the project on a digital environment, depending on the requirement. ILICE encourages communication and adaptability in interdisciplinary environment. The implementation is done on digital format with individual tabs for each ILICE activity. Required information and project status are maintained on these tabs. Information made available can be managed by supervisors, interns and the team, based on the project activity. ILICE activities are explained as follows:

### Inspire

Inspire is used to open minds through broad project contextualization. It focuses on gathering relevant information, pursuing new information, keeping track of technological advancements/trends. It influences the project's orientation. The inspire tab implemented digitally with the help of widgets, feed readers, links etc., keeps the project team updated over relevant and interesting trends, projects and things happening around them. The sample inspire tab is shown in Figure 1. *Inspire* is partial implementation of *Conceive*

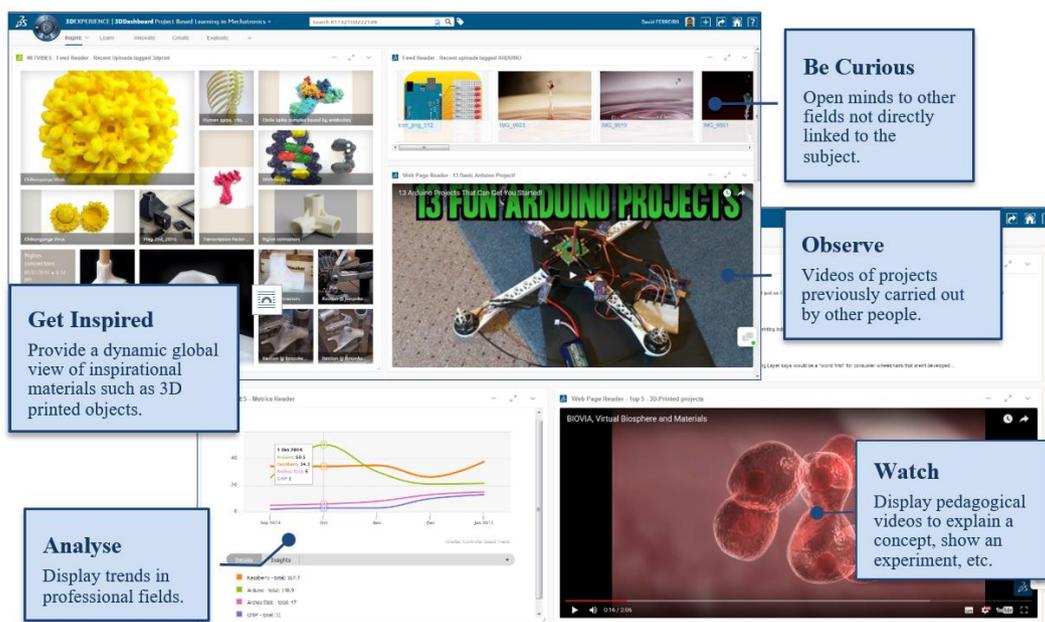


Figure 1. Inspire tab: assemble, observe and analyse

### Learn

Learn is used to provide broad access to knowledge project members, focussing on social learning, monitoring learning path, specialised learning, skill-acquisition and skill training. The Learn tab's (see Figure 2) implementation enables peer to peer learning and team help. Moreover, participants are aware of knowledge progress in the project. *Design* requires prerequisite knowledge, hence *Learn* becomes a requirement for *Design*.

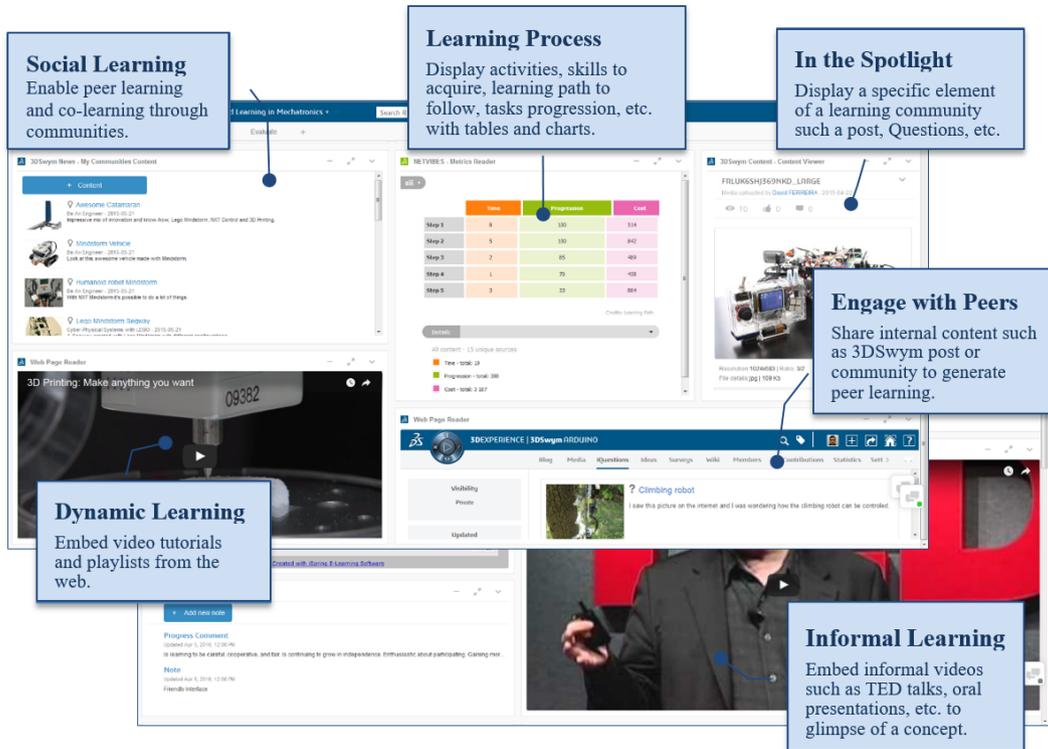


Figure 2. Learn tab: social, dynamic, peer and informal

## Innovate

Innovate focusses on co-innovation, decision making, information sharing, collaborative ideation and communication management. Using the acronym BARA “Brainstorm Anywhere, Remember Always”, the Innovate tab (see Figure 3) provides an environment for collaborative decision making. *Innovate* with *Inspire* is implementing *Conceive*.

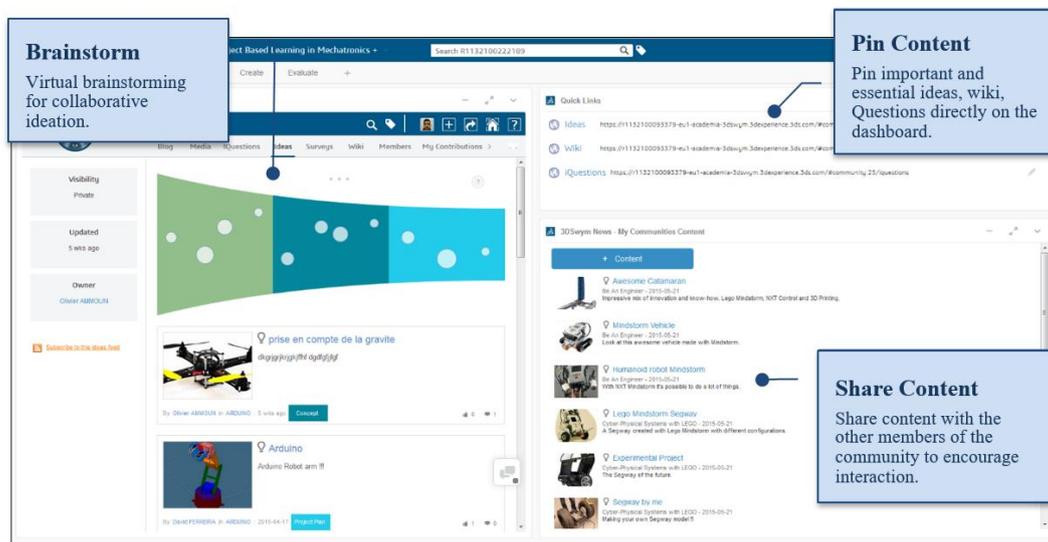


Figure 3. Innovate: brainstorm, share and collaborate

## Create

*Create* focusses on co-design, design reviews, prototyping and project management. *Create* tab is used to encourage collaborative solution creation, the *Create* tab (see Figure 4) provides the lifecycle management of the project. *Create* with *Learn* implements *Design*.

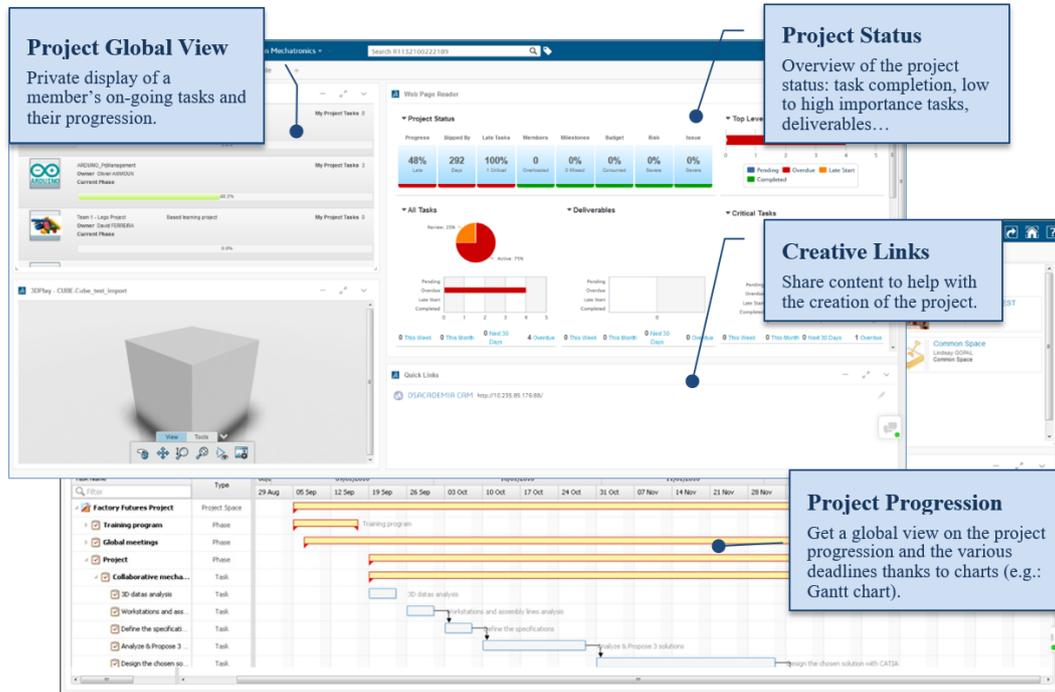


Figure 4. Create tab: design, prototype and manage

## Evaluate

*Evaluate* focuses experience feedbacks, assessments, project progress and task completions. *Evaluate* tab is used for evaluation, the *Evaluate* tab (see Figure 5) provides educators with means to mark and give feedback on the project. *Evaluate* here, partially implements *Operate*.

Table 1, summarises the roles each activity is focussed on:

Table 1. Synopsis of ILICE

<i>Inspire</i>	Get inspired from real world – contextual, semantic driven, real time, web-wide
<i>Learn</i>	Focused on discipline, subject, project practice and peer learning
<i>Innovate</i>	Convergence of ideas, wikis, persistent brainstorming etc.
<i>Create</i>	Multi-disciplinary authoring and project management
<i>Evaluate</i>	Focused on interaction monitoring, attribute-ability, instructor or peer-led



Figure 5. Evaluate tab: monitor, analyse, evaluate and manage

ILICE is non-sequential, and can be implemented over the length of the project. Learn and Evaluate can be implemented based directly on requirement to do so. Observed data, during these activities can be used to improve inspire, innovate and create activities. Due to modularity of ILICE digital implementation using tabs and digital applications, we can define/add new metrics each time we re-evaluate the project goals. The whole progress being available on IDE, it is preserved for new users (new to the project) and shows how the project evolved over time. It impacts the control and efficiency of the team involved. Dashboard with ILICE tabs are sharable with team mates and other people for collaboration. The relation for implementing CDIO may be mapped as shown in Figure 6, as shown in table:

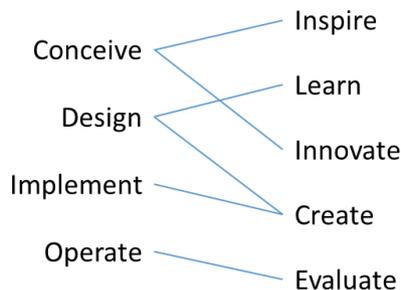


Figure 6. CDIO implementation mapped with ILICE

## INTERDISCIPLINARY PROJECT IMPLEMENTATION

### Project Introduction: Virtual Twin – Poppy Humanoid project

We present an example of implementation of a new usage-scenario for ‘Virtual Twin project’ at Learning Lab in Global Academia, Dassault Systèmes. Virtual twin project is implementation of open source humanoid robot – ‘Poppy humanoid’ (‘Poppy Project - Poppy Humanoid,’ n.d.), using 3DEXPERIENCE platform. In this, a virtual twin is created in 3D modelling environment linked to the physical robot, in order to be able to interact with it as if it was the real-physical robot. The behaviour scenarios comprise of simple imitations of body movement to complex

dynamic motions. Figure 7, shows implementation of Poppy humanoid - Virtual Twin concept using 3DEXPERIENCE platform.

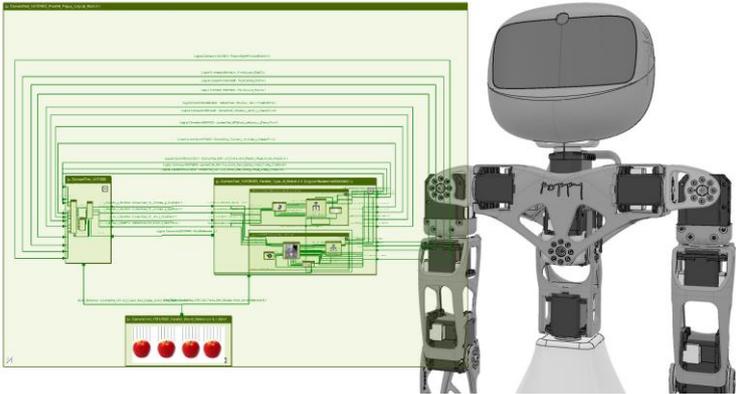


Figure 7. Previous Poppy Humanoid – Virtual Twin application

We implemented a new scenario for the existing Virtual Twin which is capable of interacting in a pre-determined manner. The new scenario is called Learning Machine. In this scenario the *twins* can observe and identify a given information (basic icons, simple polygons and polylines) and behave accordingly. The implementation was done over a period of three months. This scenario implementation requires a basic knowledge of computer aided design (CAD), computer vision, control engineering and programming – making it interdisciplinary and dependent on multiple parameters.

**Project Implementation**

The project activities implemented can be categorized in following phases, seen in Table 2, the ILICE dashboard was used depending on the requirement of each activity:

Table 2. ILICE activities mapped to project activities

Learning and assessing	←	Inspire, Learn
Proposal	←	Inspire
Defining/Achieving modular targets	←	Innovate
Combining modular targets	←	Create
Optimising final targets	←	Create
Monitored Progress	←	Evaluate
Intern assessment and Feedback	←	Evaluate
Document data and Upload	←	Evaluate

*Learning and assessing requirement ← Inspire, Learn ← Conceive, Design*

The project started with a new participant. The participant had basic knowledge of CAD engineering and programming. Initially, time was spent to study the existing model and reproduce it by implementing it from scratch. The knowledge required to reproduce the models were gathered at one place under Learn tab in dashboard. It had video introductions, video tutorials, and links to documentation of prerequisites to work on the project. The participant had to spend a few of weeks to get used to the content and the working environment. The

learn tab looked like as shown in the Figure 8. The inspire tab provided the participant with knowledge of activities happening in related fields.

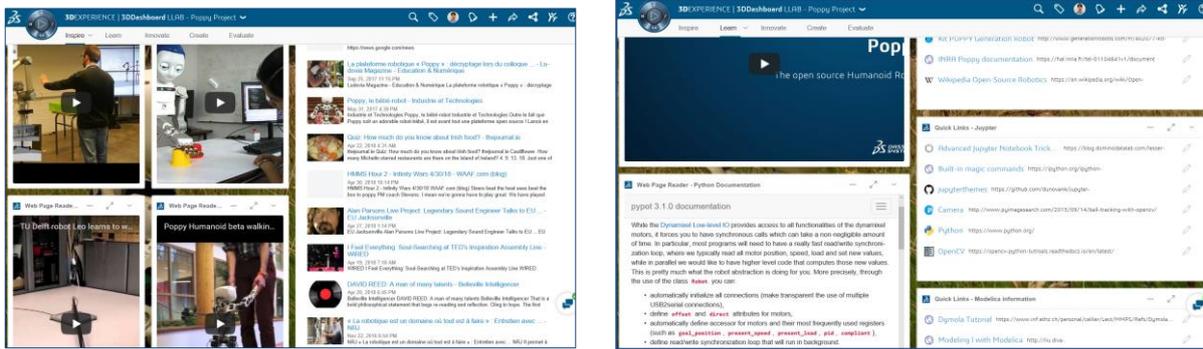


Figure 8. Showing Inspire and Learn tab for Virtual Twin Project

*Proposal* ← *Inspire* ← *Conceive*

Based on time spent on learning activity participant had to propose a new scenario that can be implemented on the existing model. The previous implementations (see Figure 7) have implemented concepts like linking the robot with different platforms – IPython notebook, Requirements Functional Logical Physical (RFLP), Modellica/ Simulink platforms - to implement basic scenario of Virtual Twin Concept, Dynamic behaviours, following a path using reverse kinematics. The participant had to build upon the implemented ideas and come up with a new scenario.

After thorough study, the focus was set to ability to identify and act accordingly. A primitive classification of proposal looked like as shown in Figure 9. The participant also came up with the probable execution plan which can be referred to in future.

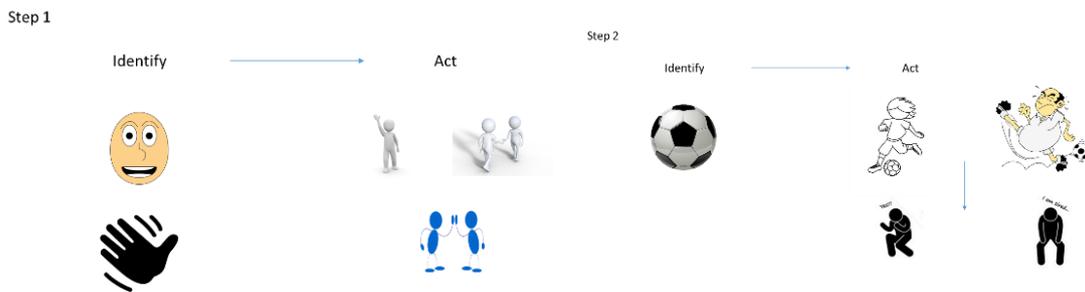


Figure 9. Initial proposal based on learned and inspire material

*Defining/Achieving modular targets* ← *Innovate* ← *Conceive*

The next task was to assess the time required to complete each tasks and hence, break it down in small targets which can be achieved separately and added to build upon. The small targets set were as follows:

- Identification of visual information – the robot had to identify an image shown (Figure 10), initially in form of icons and then in form of randomly drawn pattern on paper or drawing tools.



Figure 10. Target images for initial recognition: icons and freely drawn polylines

- Ability to move body parts – being able to move different body parts with certain precision and accuracy and get the feedback of movement from the robot.
- Communicate simulated information to and from virtual twins – asking virtual twin to act in simple motions like rotation of one of the body parts and receive the feedback and check for errors if any.
- Documenting each individual task - each individual task needed different pre-requisite skills and were documented accordingly for assembling the tasks together.

*Combining and optimising the modular targets ← Create ← Design, Implement*

The modular targets were then join together to have continuous flow of information which is used by next component in the process and it becomes a loop-cycle. Like, the robot identifying the visual information → logical unit → performing dynamic action → feedback of motion → logical unit → optimise for error → performing dynamic action. The model was then optimised to check for false negatives/positives which might occur while performing simulation in different backgrounds. The modular targets and its combination were implemented and monitored in following order. The modular tasks management was carried out as per the chart organised as shown in Figure 11.

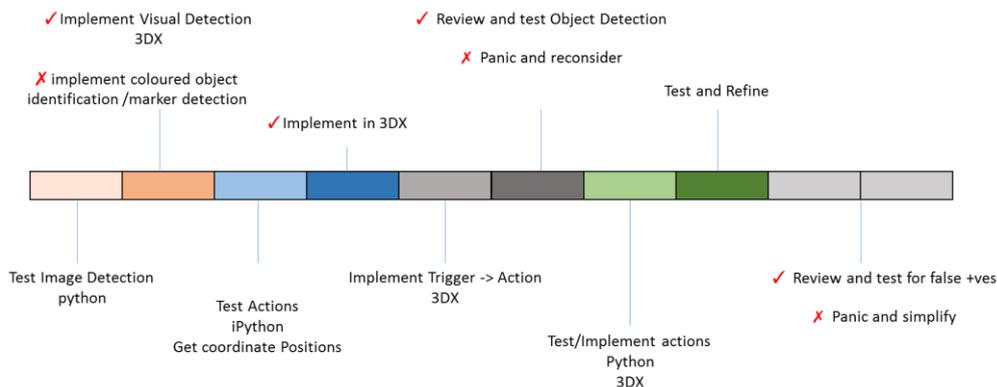


Figure 11. Proposed task schedule for the project

*Monitored Progress, Project assessment and Feedback ← Evaluate*

The whole process had various components and had to be monitored regularly in order to work effectively. The physical designs and logical components were kept in using pie chart as shown in Figure 12. The assessment was done weekly and the project team was reset the target accordingly for the coming weeks.

At the end, the whole documentation was assembled and together and made available online to be used as a new standard example for virtual twin project, as seen in Figure 13. The documentation included tutorials and basic packages required to run the new scenario, just after importing data into the system.

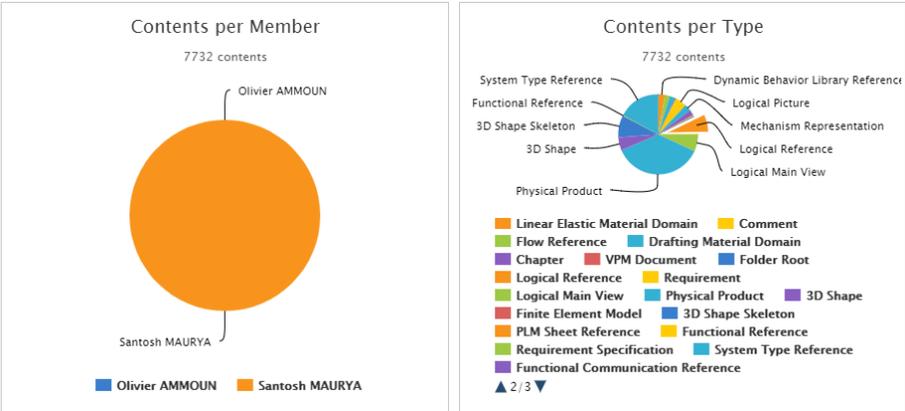


Figure 12. Project component analysis

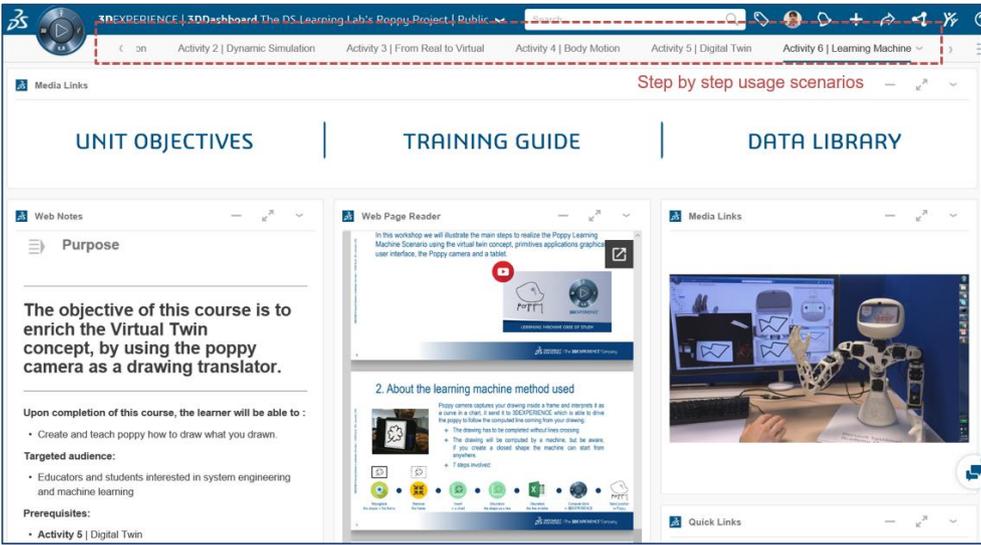


Figure 13. Documented package: available for learning and applications

**ILICE RELATION TO CDIO SYLLABUS**

Based on the experience from implementing the discussed project, we mapped “creation of ‘Poppy Learning scenario’ using ILICE framework” to CDIO Syllabus 2.0, as shown in Table 3. In order to propose, validate, complete and communicate the project activities, specific attribute/skills were focussed in the duration of conducting the discussed internship. The attributes can be largely categorised as technical and non-technical (social, entrepreneurial, management, communication, etc.). The main attributes observed during the project, are mentioned in the Table 3, alongside their requirement during different activities of ILICE.

Table 3. Skills used relevant CDIO Syllabus 2.0 attributes

CDIO Syllabus 2.0	I	L	I	C	E	skills/ attributes
DISCIPLINARY KNOWLEDGE+ REASONING		•		•		basic engineering knowledge
PERSONAL AND PROFESSIONAL SKILLS		•	•			<ul style="list-style-type: none"> <li>– analytic reasoning and problem solving</li> <li>– experimentation, investigation &amp; knowledge discovery</li> <li>– trade-offs, judgment and balance in resolution</li> <li>– creative thinking</li> <li>– lifelong learning and educating</li> <li>– time and resource management</li> </ul>
INTERPERSONAL SKILLS			•	•		<ul style="list-style-type: none"> <li>– communication</li> <li>– technical and multidisciplinary teaming</li> </ul>
THE INNOVATION PROCESS	•	•	•	•	•	<ul style="list-style-type: none"> <li>– appreciating different enterprise cultures</li> <li>– technical entrepreneurship</li> <li>– new technology development and assessment</li> <li>– conceiving, system engineering and management</li> <li>– designing, implementing, operating</li> </ul>
Extended CDIO Syllabus			•		•	leadership

### ILICE implement-ability validation

Incorporating PBL requirements and CDIO Syllabus, ILICE framework is flexible to accommodate wide range of project centric methodology. It has been implemented on Virtual twin Project over each implementation of its usage scenarios and other projects focusing on Structural engineering, 3d printing, Arduino projects, etc. It is currently being used in several ongoing projects in higher and secondary education, in single classrooms and internationally dispersed institutions as well (Fouger, 2016). It is fully customizable by educators and can be accommodated to project's requirements and complexity.

### CONCLUSION

We proposed implementation of CDIO methodology for implementing complex projects in an industry environment. We discussed ILICE framework to in order effectively implement CDIO on integrated digital frameworks. The ILICE frameworks provides an easy to comprehend way to learn, create and manage projects requiring multiple fields of expertise or collaboration. The example usage scenario shown, discusses one such implementation of ILICE, and this ILICE implementation is now available if anyone one wants to learn and implement the project, or, continue working on their own with this as there basis. The end-documentation allows the project to be implemented, managed and improved on within a team with people having basic knowledge in the required field.

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## BIOGRAPHICAL INFORMATION

**Santosh MAURYA**, is a PhD candidate in Engineering sciences and Design, Department of Mechanical Engineering and, part of Academy of Global Leadership (AGL), leading graduate program, from Tokyo institute of Technology. His current research focuses on facilitating engineers and designers at the concept design stage of the product design process, by usage of co-design method and mixed reality environment for creating innovative products, more personalized and relevant towards end-users experiences.

**Olivier AMMOUN**, is Head of the Dassault Systèmes Learning Lab  
Olivier founded the Dassault Systèmes Learning Lab in 2015. His responsibility includes defining, implementing, documenting, testing and deploying new innovative Digital Learning Experience.

The Learning Lab act as a centre of excellence where new pedagogical methods and emerging Industry Renaissance practices are combined thanks to new collaborative, social technologies and cutting-edge 3D solutions to implement new learning experiences. More than a showroom, it wishes to implement educational transformations in order to better prepare engineers for industry renaissance. Learning activities are developed in collaboration with schools and industries all around the world to maximize the benefits of the latest generation of Dassault Systèmes' solutions: The 3DEXPERIENCE Platform.

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