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TRANSFERRING DESIGN SKILLS FROM FRAGMENTED TO INTEGRATED APPLICATION

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ABSTRACT
In the academic years 2016-18 we have been working on integrating various design skills[1] in order to achieve deeper and more sustainable learning. In the past we taught our first and second year students these skills to achieve perfect drawings and beautiful prototypes. Most students passed these classes with great success. But when the classes were finished, students were still not able to apply these skills in a more complex context of a design project.
By offering just in time (JIT) design skills workshops during integrated design assignments, students will be reminded of the isolated skills they have learned earlier in the semester and will know how to apply them in a meaningful context as outlined by Merriënboer, Clark & Croock [3]. This will lead to deeper and more integrated learning because students feel a higher level of urgency in using these design skills in a useful context. They then also need to figure out which type of skills are the most suitable for their assignment. In this way students will be more intrinsically motivated and reach a higher level of autonomy according to Deci & Ryan [1] and Dochy, F., Berghmans, I. Koenen, A. en Segers, M. [2]. The authors investigated how a higher level of integration of design skills can be achieved while preserving the control level for each individual skill.

Keywords: Design Education, Didactics, Deep Learning, Integrated learning, Intrinsic motivation

1 PROBLEM DEFINITION

Before the academic year 2016-2017, design skills like sketching, 3D-CAD and proto modelling were taught as isolated subjects, which were individually assessed. In this setup, students were able to reach a high level of technical control in each separate skill; however the students proved to be unable to apply these skills on the same high level in the context of the following design projects.
During a conference meeting in 2017 of various Dutch and Belgium schools for product design engineering (Windesheim, Han, Howest & Saxion), the demands and didactics of teaching design skills were discussed. At the Industrial Design Engineering Department of Windesheim in Almere the design skills are taught in integrated assignments in which various design skills are combined. In their experience this leads to a higher level of understanding for more experienced students, however this tends to be too complex for starting students. At the other schools they expressed a wish for more integrated assignments, however presently the various design skills were still taught there as isolated subjects.
In order to reach a higher level of transfer of knowledge and skills to the design projects, it would be desirable to practice more on the application and integration of the various skills in a meaningful context. On the other hand enough time and effort should be invested in practicing the basic skills, and expanding the level of integration when students are familiar with these basic skills.

[1] Design skills within the Educational Programme of Industrial Design Engineering consists of: sketching, graphic design, design theory (including the ergonomics involved), proto modelling, 3D-CAD modelling.

2 The 4C-ID and HILL model

2.1 Explaining the 4CID model for complex learning

The Four Component Instructional Design model (4C-ID) by Merriënboer, Clark & Croock [3] is based on the holistic vision that for deep learning, a clear view of the broader picture is needed in order to see where the knowledge or subtask fits in the complex context. The model starts with simple tasks and builds up to complex cases, but even at the simple task level it is vital to always show where the knowledge fits into the complex whole. The level of guidance starts high and will be lowered while the skills of the students increase (scaffolding). Experts have structured their knowledge in extensive cognitive schemata. Therefore they can access and apply their knowledge in varying relevant contexts. Students don't have these cognitive schemata yet and have to form these by applying knowledge and skills in different contexts to become aware of the broader relevance. Variation in tasks is therefore important to promote the transfer of knowledge and expand the cognitive schemata of the students. The most important aspect of complex learning according to the model is the construction of these cognitive schemata by converting concrete examples into process-schemes.
The 4C-ID model by Merriënboer, Clark & Croock [3] distinguishes recurrent and non-recurrent tasks. Recurrent tasks ask for knowledge of the task-rules plus a lot of practice to automate these tasks. When these tasks are sufficiently automated, a student will not have to think about them anymore and can therefore concentrate on the non-recurrent tasks. Non-recurrent tasks ask for strategic insight on which method and procedure maximises effectiveness to complete the task.
In order to achieve deep learning, the 4C-ID model claims that four components are needed: An authentic learning task which places a task in a realistic context; supporting information needed to complete a task; just-in-time (JIT) information which is needed during practice (and therefore also welcomed by the students) and needs to be tuned to foreknowledge; and part-task practice to automate subtask knowledge and skills.

2.2 Explaining the HILL model

High Impact Learning that Lasts (HILL) starts out of a sense of urgency or a realistic problem. Dochy et al. [2] state that a student should be in control of the process in order to solve this problem. During the process there should be collaboration and guidance, a hybrid learning environment, active ways of knowledge sharing by the students and flexibility in formal and informal learning settings. According to Dochy's HILL model [2], the class will be finished by an assessment.

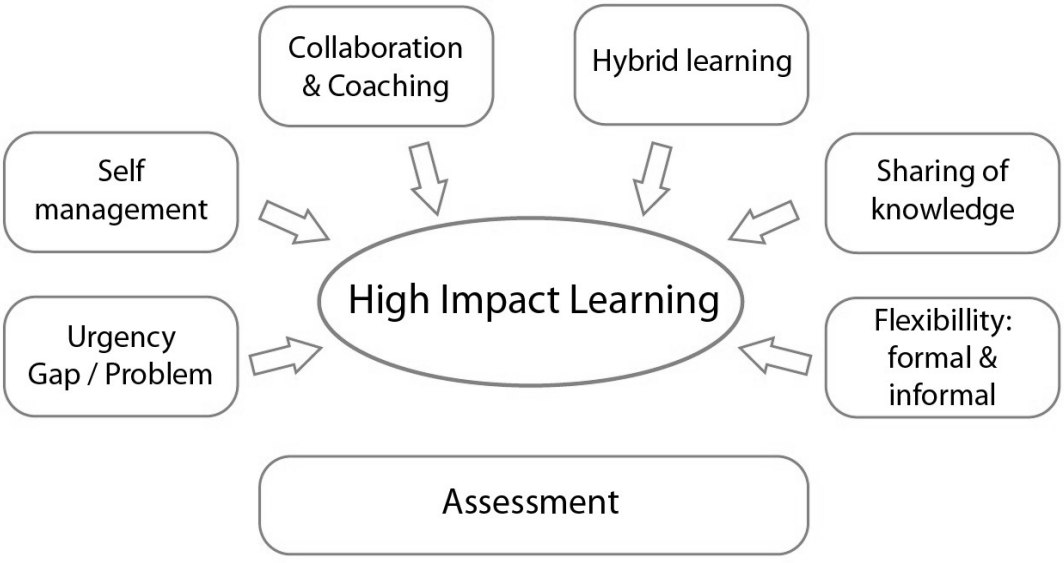

Figure 1. Building blocks of the HILL-model. (Dochy, 2015)

The intrinsic motivation can be boosted by giving the students a choice between different subjects and assignments, as outlined by Deci & Ryan [1]. Information to the students is supplied on demand and just-in-time as much as possible. In that way students feel the urgency more because they need the information to complete a task. For teachers this means they have to monitor the demands and wishes of the students and they have to be flexible enough to respond to these changing needs of the students. During this whole process feedback between students and teachers plays an important role according to Hattie and Timperley [5] in helping to achieve high impact learning.

3 INTEGRATED LEARNING SETUP AT ROTTERDAM UNIVERSITY

3.1 Place of the design skills classes in the curriculum

At the Industrial Design Engineering department of Rotterdam University, design skills are taught in four semesters in the first and second year. The class-line consists of basic skills for visual communication and form development needed in the design process. The skills that are taught in these classes are sketching, graphic design, design theory (including the ergonomics involved), proto modelling, 3D-CAD modelling.

The authors have based the re-development of the class-line on the 4C-ID model of Merriënboer, Clark & Croock [3] and the HILL model of Dochy et al. [2]. The goal of the redesign was to achieve a deeper understanding in the use of the various design skills as tools in a design process by building up the four classes towards integrated assignments in an authentic context. The four classes build up in skill level, level of integration of various skills as well as complexity of context. At the end of the fourth class our students should be fully prepared to apply the various skills in the context of authentic design projects.

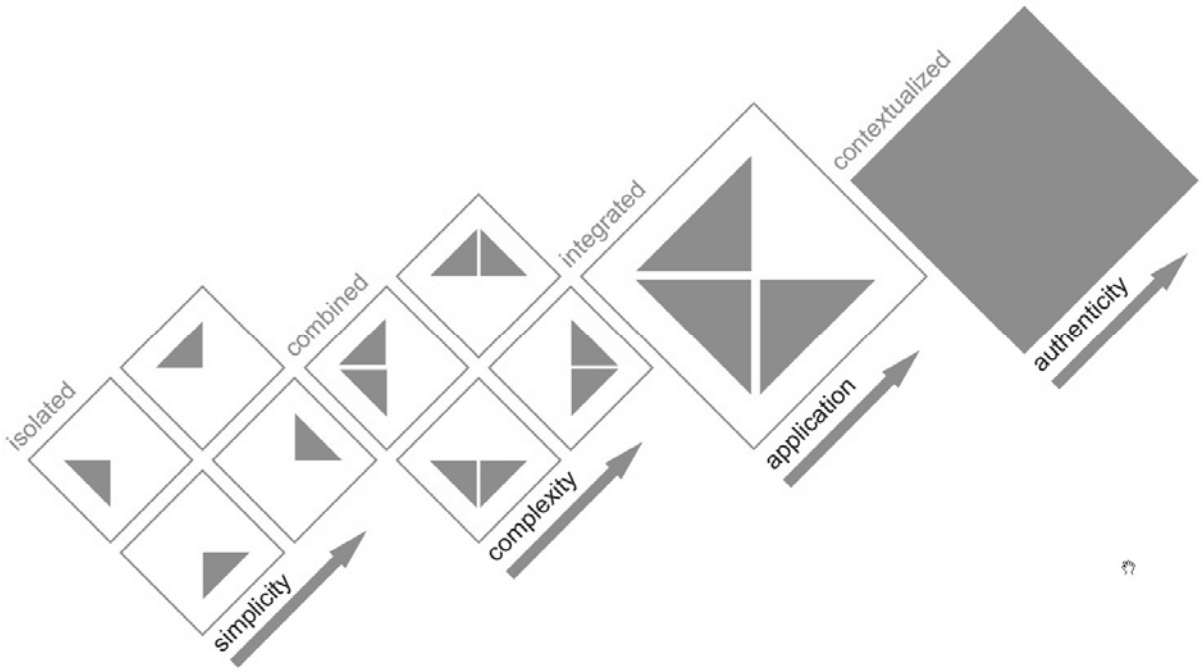

Figure 2. Design Skill Transfer model 2018

3.2 Description of the four design skills classes

Table 1. Design Skills class-line 2016-17

DSX10	DSX20	DSX30	DSX40
Semester 1 (yr 1)	Semester 2 (yr 1)	Semester 3 (yr 2)	Semester 4 (yr 2)
6EC	6EC	4EC	4EC
Students that participated: 98	Students that participated: 92	Students that participated: 72	Students that participated: 81
Teachers involved: D.H.M. Bekker M.C. Zuijderduijn J.Vrolijk	Teachers involved: D.H.M. Bekker M.C. Zuijderduijn J.Vrolijk	Teachers involved: H.T.P. Hulst G. Hlavacs	Teachers involved: D.H.M. Bekker H.T.P. Hulst J. Zijlstra

DSX10

This design skills class-line (see table 1) focusses on the first step in sketching, prototyping and 3D-CAD. During this first semester the level of integration was still low. A central theme was chosen as subject for the various skills (modelling of LEGO parts) however all skills were practiced in isolation. Still for each skill the teachers involved explained its value and place in the broader design process. The main accent in this class was on practice and automation of the various design skills.

The assignments had a certain level of simplicity and for each assignment clear examples were given of the desired finished level. The level of guidance was very high and students were corrected a lot in order to master the techniques involved. In line with Dochy's theory [2], students got a lot of feedback during this class.

DSX20

This design skills class focused on the next level of sketching, prototyping and 3D-CAD.

Some skills were combined in one assignment to achieve more complexity, others were still isolated. Students also experimented with design and ergonomics theories. They used the various skills to work more towards one end-result. Focus in this class was still mainly on practice and automation of the skills (on a higher level than in semester 1); however the assignments included more interaction between the various skills. For the theory some online instructions (flipped classroom) were used, but the level of guidance by the teacher was still high.

DSX30

This design skills class focused mostly on 3D-CAD modelling of complex shapes combined with sketching, proto modelling and ergonomics. In the third semester students were working on one central case in which they made a redesign of a handheld electronic instrument with a complex shaped form. In this assignment students could no longer just practice the isolated skills, but also had to apply them in a meaningful and integrated way to improve existing designs according to their own wishes. Theory and some practice assignments were placed online. In this class the guidance focused on strategies for application of the skills in the individual design process of the students.

DSX40

In the fourth semester all design skills were integrated into one assignment: sketching, proto modelling, ergonomics, design theory and 3D-CAD. In this class the students were free to choose one of four themes (medical, mobility, public space or outdoor) and choose their own design vision for the product they wanted to design. The students made their own decisions in how and when to apply the various design skills in their design process. The level of guidance was low and focused on strategies on how the students could express their vision best in their designs. The class consisted of a few lessons in which the students prepared and decided on the type of product and product vision they wanted to work on, followed by a two week 'design marathon' in which they realised their design. The authors choose for this intensive 'marathon' setup to achieve a more authentic context in which the professional practice for industrial design engineers was simulated as closely as possible and the students could focus solely on the DSX40 assignments, while not being distracted by other classes. Students got Just-In-Time workshops and feedback during these weeks, which they could apply directly into their designs.

4 RESULTS 2016-17

DSX10 and DSX20

In the first and second semester the changes where relatively small compared to the old setup so the results remained largely the same. Skills were mainly being taught in fragmented and isolated assignments. The workshops for the prototyping skills have worked very well. Students had one whole day to complete an assignment and during such day a lot of information and feedback was given to the students. The 3D-CAD modelling assignments were based on basic training lessons preceding the end assignment case. Based on one central LEGO theme for CAD, students had a clear example to work up to. They could also choose their own theme, which boosted intrinsic motivation for the students. Many results exceeded the desired level. The use of a central theme, like LEGO in the first semester, proved a bit artificial and hard to combine in one assignment with sketching and prototyping skills. These skills were partially combined in the second semester, which created a more complex learning context. Still most of the assignments were presented to the students in a fragmented way.

DSX30

In semester 3, it proved to be too big a step for the students from practicing the different skills in isolation to applying and integrating them in their own design. For example sketching an existing design is a lot easier then searching for a right form using sketching as a tool. Students also had to make choices on which kind of prototypes were best for their goal and how to set up a 3D-CAD model for their own design. The result was that the level of the various skills as shown by the students was lower than in the preceding years. However the students were more motivated because they were not merely copying existing products but also improving the design according to their own wishes.

In this semester we partly worked with practice assignments and online theory instructions to prepare students for the main assignment (flipped classroom instruction). In the end we saw a big difference in the results of students who always prepared themselves by doing the home assignments and those students who did not prepare well. The latter still had to concentrate too much on mastering the basic skills in the class and therefore had problems with the setup of their own design and applying the various skills in the context of their own design. During this semester the bandwidth of the assignment was still limited because the teacher predefined the subject and steps in the design process.

DSX40

The two week intensive class (design marathon) combined with the freedom for the students in choosing a given theme and design vision worked well for the motivation of the students. Combining the different design skills also gave students the freedom to mix and combine these skills as needed for their own design. Coming up with a distinctive and critical vision proved too difficult and time consuming for most of the students. Working with different teachers during the two weeks gave students a broad diversity of feedback on their work.

5 CONCLUSION

Within the second year classes DSX30 and 40 it proved to be difficult for the students to practice all design skills at the desired high level. Through semester evaluations of these individual classes with the students and teachers involved, the authors found out that a lot of time was being invested in the application and organisation of the skills in a meaningful context as a whole, and not just solely in the practice of these isolated skills. Learning these skills in a fragmented way first is crucial as a first step towards automation and application in an authentic context later on. In order to automate the fragmented skills the students learned earlier in the DSX10-20 classes, these skills had to be repeated and practiced further in the DSX30-40 classes, which took extra time from both students as well as teachers. But the accent in the DSX30-40 classes was placed on the application of the skills in order to improve the level of transfer of learning by the students and the construction of their cognitive schemata as mentioned by Merriënboer, Clark & Croock [3]. And in fact, in our (first year) design projects for this year (2017-18) the authors can already see that our students apply the various fragmented design skills they learned in the DSX10 and 20 classes at a higher level than last year since the authors started with the new class-line.

6 RECOMMENDATIONS FOR DIRECT IMPROVEMENTS

1] In the assignments that teachers give to the students, the teachers can predefine larger parts. For example they can let the students choose from predefined design visions and let them concentrate on how they can express this vision in their design instead of losing a lot of time on thinking of a good design vision. The teachers can also build up their classes in more sub-levels to let the students grow accustomed to higher levels of integration more gradually. Showing clear and good visual examples for each level is key for this integration.

2] For the grading of the students work we use rubrics with all criteria described in text at three levels. Explaining the rubric with good visual examples for each of these three levels will help students (and teachers) interpret and understand the criterion texts more clearly.

3] The authors would like to work towards an even higher level of integration by combining more knowledge based classes within the curriculum of the Industrial Design Engineering department into knowledge & skills cases. These cases would be a sort of light-version of our design projects, which would focus purely on the practice and application of the knowledge and skills in a design, without focusing on the broader competences belonging to the regular design projects. With these improvements we believe that our class-line methods will lead to a deeper, more sustainable way of learning the design skills for our Industrial Design Engineering students, as well as transferring the knowledge and control level of these skills into an authentic and professional setting.

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