Experience-Based Learning in Construction Education; Testing the Effectiveness of the Product-Oriented Learning Situation

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ABSTRACT: Learning in general, and at universities of the arts, design, and architecture in specific, is a personal experience. As the result of a wide variety of content and daily experiences, each aspiring designer uses a different approach to acquire knowledge and understanding to tackle the challenges ahead. However, since learners in western countries share a similar environment and a comparable context in which they operate, learning approaches between learners show great similarity: learners from the same generation are likely to learn similarly but differently to previous generations and generations to come. Based on these developments, learning situation design should adapt, so as to support novel learning approaches effectively.

To include learning approaches shared by generation Y and Z in education, this study presents two learning situation designs that were tested at architecture schools in Belgium and the Netherlands during workshops of structure courses. Based on these tests, the effectiveness of the designs is calculated using effect sizes in comparison with reference studies. Finally, differences in effect sizes between the studies are discussed, based on social effects, background, and context effects.

1 GENERAL INSTRUCTIONS

1.1 *Learning in Complex Environments*

Architecture and design students in the 21st century are confronted with multifaceted and interdisciplinary challenges. In studio exercises learners collaborate with designers and engineers to go beyond the strict disciplinary boundaries (Andersson and Andersson, 2006). Based on this development, two challenges emerge. Firstly, the traditional disciplinary position of engineering courses does not necessary allow for knowledge acquisition, fit for multifaceted and interdisciplinary use. Rather than learning strict structural procedures and strategies, currently a shift to a focus on understanding of concepts and first principles in real-world situations (e.g. studio exercise, multi-disciplinary project) has occurred (Redish and Smith, 2008). By reaching for higher levels of understanding and a real-world necessity to design with structural knowledge, knowledge becomes more valuable and is more easily retained. Secondly, when environments change, our learning approaches adapt in order to structure and understand contemporary events. For example, in simple and static environments, learners are more likely to learn by isolated specifics, and in complex and fluid environments, learners shall form learning approaches grounded in development and change. Therefore, students in university today that are raised in a digital environment based on progress and development, presumably have established different learning approaches compared to learners of previous generations. According to generational theories, Generation Y (born between 1980-2000) have adopted a trial-and-error approach to problem solving, based on doing rather than knowing (Paine Schofield and Honoré, 2009), and they want to create using the tools of their time (Prensky, 2010, p. 19). Since Generation Z (born after 2000) has entered our university just recently, not much is known about the learning approaches adopted by this group of students. However, based on early studies, these students appear to learn more effectively through observation and experience than previous generations (Shatto and Erwin, 2017). Accordingly, so as to support contemporary learning approaches in universities today, there is a need for activity-centered learning situation designs in order to provide effective teaching and learning outcome. Based on these developments, this study presents two tested learning situation designs. In addition, suggestions for learning situation choice are introduced based on the learning context, and the learning aims. For the research context, structure courses at universities for architecture and spatial design in Belgium and the Netherlands are used.

1.2 *Learning Situation Design*

In activity-centered learning situations, the activity can be introduced at various parts of the design. The position of the activity in the learning situation design may influence the character of the learner's understanding, and could therefore support some learners better than others. For this study, three types of learning outcome are distinguished: (1) *surface understanding*, (2) *deep understanding*, and (3) *conceptual understanding* (Hattie, 2012, pp. 60–63). In a (1) surface understanding, the learner understands a concept in relation to a context. In a (2) deep understanding, the learner understands a collection of related concepts in relation to a context, and in a (3) conceptual understanding, a learner understands a concept independent from a context (Klausmeier, 1973). In order to provide learners with rich knowledge, in this study, deep understanding and conceptual understanding are addressed and surface understanding is not.

So as to support various learning approaches and learning aims, for this study the (1) *Product-Oriented Learning Situation*, and the (2) *Process-Oriented Learning Situation* are introduced (Figure 1) (Vrouwe and Luyten, 2015). These learning situations consist of three interactions (i.e. blue aspects), and three learning outcomes (i.e. pink, green, and orange aspects).

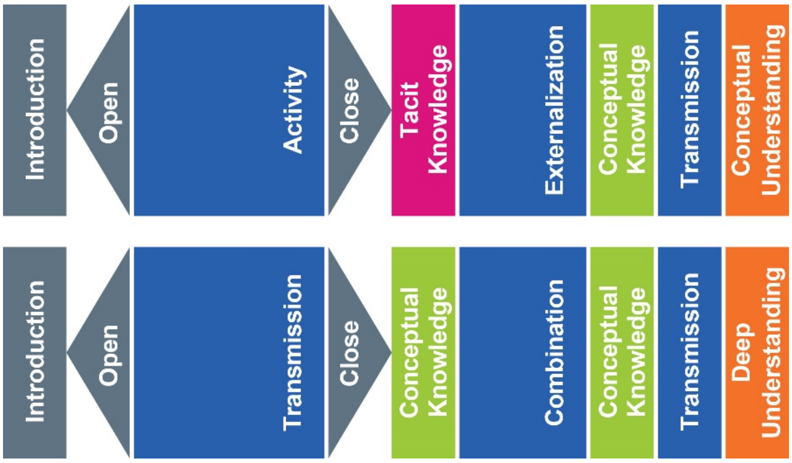

Figure 1. Schematic visualization of the product-oriented learning situation (A), and the process-oriented learning situation (B).

- Activity: Learner participates in a goal-directed undertaking (e.g. play, learning, and labor) (Illeris, 2007, p. 58).
- Externalization: Learners participate in a dialogue that enables the articulation of individual perspectives. Through these dialogues, tacit knowledge is revealed, recognized, and structured (Nonaka, 1994, p. 20; Shibata, 2006, p. 7).
- Transmission: Learners are part of an environment where an external person like a teacher or instructor is transferring something (e.g. classroom instruction and lectures) (Illeris, 2007, p. 100).
- Combination: Learners participate in an interaction in which existing explicit knowledge is applied, articulated, and developed into a concrete form (Nonaka, 1994, p. 20; Shibata, 2006, p. 7).
- Tacit Knowledge: A kind of knowledge that cannot be verbalized, declared, or articulated in a formal language (Pathirage et al., 2008, p. 206).
- Conceptual Knowledge: An objective type of knowledge that can be retrieved from the memory, and can be reflected on consciously (e.g. Facts, Concepts, and Events) (Ashcraft, 2013, pp. 211–213).

In the (1) Product-Oriented Learning Situation (Figure 1A), learning is initiated by the construction of an architectural structure. In the interaction of ‘Activity’, the learner builds a structure which is likely to results in ‘tacit knowledge’. In the interaction of ‘Externalization’, the learner is supported in the conversion of tacit knowledge into ‘Conceptual Knowledge. In this process the knowledge of making is converted into knowledge that can be shared and discussed. In the interaction of ‘Transmission’, the learner is supported in the formation of a ‘Conceptual Understanding’, based on the experience of the construction made. Because this learning situation includes self-learning, and a conversion of one type of knowledge into another, it is more likely conceptual understanding is formed.

In the (2) Process-Oriented Learning Situation (Figure 1B), learning is initiated by the cognitive process of designing an architectural structure. In the interaction of ‘Transmission’, the learner is introduced to the concepts needed for the course. This interaction is likely to results in ‘conceptual knowledge’. In the interaction of ‘Combination’, the learner uses the knowledge formed in the previous interaction in the construction of an architectural structure, which is likely to result in a ‘deeper Conceptual Knowledge’. In the interaction of ‘Transmission’, the learner is supported in the formation of a ‘Deep Understanding’ of the construction made. Because this learning situation includes multiple approaches in which conceptual knowledge is addressed, deep understanding is more likely to be formed.

2 DATA COLLECTION

2.1 *Research Design*

For the interaction of ‘Activity’ and ‘Combination’ (Figure 1), a construction workshop was used. In this workshop, the participants were challenged to design and construct a span of 1000mm (Figure 2L) using bamboo skewers, elastics, and rope. After finishing the multiple interactions of the learning situation, the structure was loaded with bottles of water, attached to the middle of the structure. The load was gradually increased until the structure collapsed. Finally, a score was calculated by dividing the load attached to the structure (P) by the weight of the structure itself (G) (Figure 2R).

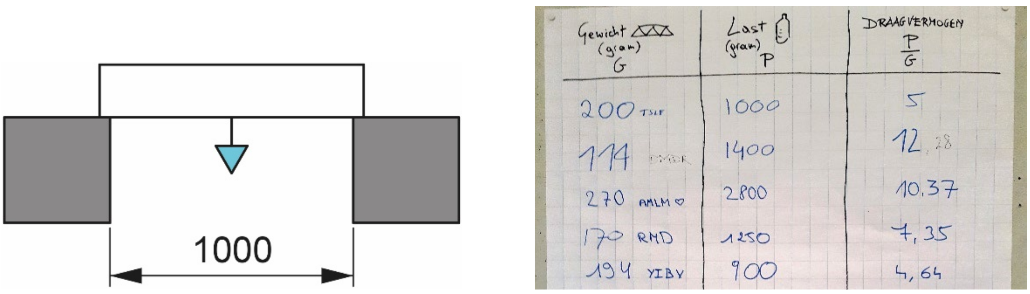

Figure 2. Set-up and dimensions of workshop exercise (L), and a selection of test outcome scores (R).

To test the product-oriented, and the process-oriented learning situation, two between-subject research designs are made. The first research design (Figure 3L) is made in order to scale the difficulty of the various measurement instruments introduced. Firstly, a group of learners is divided into two (Group A and B). Then, each of the groups are introduced to the product-oriented learning situation. Next, after each interaction, the participants finish a quiz (section 2.2) to provide a measurement for learning improvement. In this research design, quiz A and quiz B are interchanged in group B in order to compare the learning improvement between the groups. Based on these results, outcomes are scaled with the intention to avoid differences in quiz difficulty and improve measurement reliability.

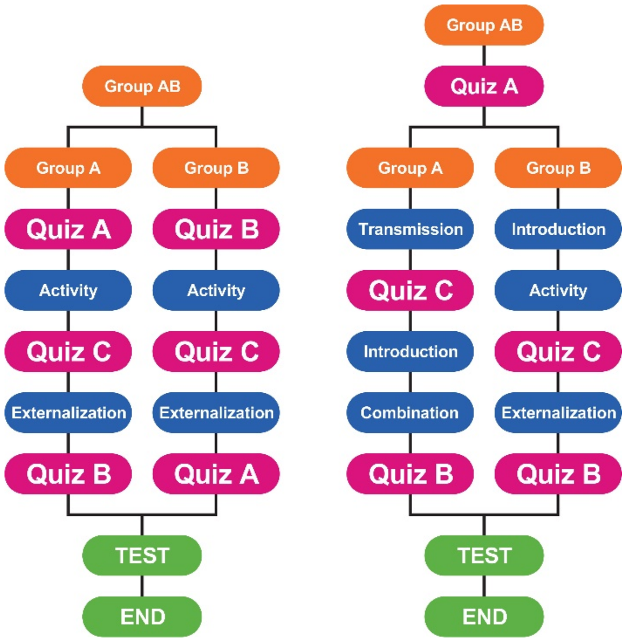

Figure 3. Between-subject research design to compare and scale the quiz difficulty (L), and between-subject research design to compare learning situation design effectiveness (R).

The second research design (Figure 3R) is made to compare learning improvement of the product-oriented, and the process-oriented learning situation designs. In this research design, a group of learners is firstly divided into two (Group A and B). Then, one of the groups is introduced to the process-oriented learning situation (Group A), and the other group is introduced to the product-oriented learning situation (Group B). Next, as with the first research design (Figure 3L), after each interaction the participants finish a quiz (section 2.2) to provide a measurement for learning improvement. In this research design, the same sequence of quizzes is used.

In order to compare the learning improvement as the results of the within-subject and between subject learning situation designs to teaching-learning approaches, the data from 'Visible Learning', a study by John Hattie (2012) is used. This study contains a set of meta-analyses of a large amount of research articles, and ranks teaching-learning approaches based on *effect size*. The effect size as used in visible learning is calculated by the following equation:

$$\text{Effect size} = (\text{Average (Post-test)} - \text{Average (Pre-test)}) / \text{Standard Deviation}$$

Based on this formula, for teaching-learning approaches to be effective, Hattie adopts a score of 0.4 as a minimum. Based on this score, for this study four effect sizes are used for reference: Feedback (0.75), Prior Achievement (0.65), Problem Solving Teaching (0.61) and Student-centered teaching (0.54) (Hattie, 2012, pp. 166–168).

2.2 *Measurement Instruments*

As a measurement instrument, quizzes are used. As discussed in the previous section, the quizzes are completed after each subsequent interaction. As a medium for the quizzes, Socrative software is used. This software can be used on conventional digital interfaces like laptops, tablets, smartphones.

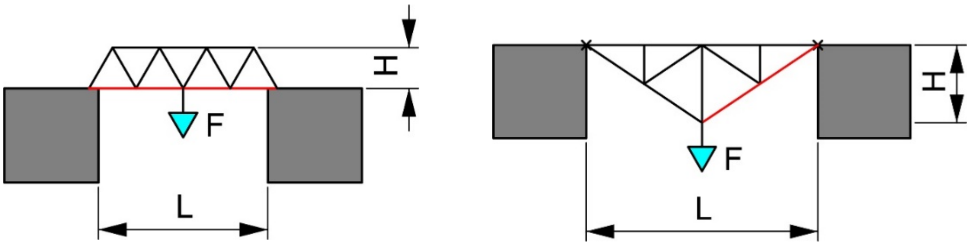

Figure 4. Examples of images used in the quiz questions: V-Truss (L), and inverted English Truss (R).

Each of the three quizzes introduced consists of five multiple choice questions and five questions using a scale from 1 to 10. In the multiple-choice questions, the participant is presented a visual representation of a structure using lines, and a load is indicated using a blue arrow (Figure 4). Next, three statements are introduced of which one is true. For example, one of the statements can be: ‘The red structural parts in figure 4L can be replaced by a strong cable.’ In a following question, the participant is asked how sure he or she is of the previous answer using a scale from 1 (not sure) to 10 (very sure).

In addition to the quizzes, the participants were provided with a survey after completing the research design as presented in Figure 3. In this survey, two closed-ended and two open-ended questions were introduced. In the closed-ended questions the participants were requested to scale the amount in which the interactions have contributed to success in the quizzes with a score ranging from 1 to 5. In the open-ended questions, the participants were requested to list the strong and weak points of the learning situation design, and to rate these aspects with a score of importance ranging from 1 to 5.

3 DATA REPORT

The research designs as presented in Figure 3 are completed at 2 different universities. [1] The first research design was completed at Willem de Kooning Academy, Rotterdam University of Applied Sciences, spatial design (WdKA). In the bachelor programme of spatial design, project-based learning lies at its core. In contrast to Beaux-Arts programmes, where design studios and technical supporting courses are worked on independently (van Zeijl, 1989), at WdKA all participating teachers/ tutors contribute on an equal footing to the project. Based on this learning approach, collaborations with so-called ‘Stations’ (i.e. workshops for wood, print, textile, metal, etc.) lies at the core of this programme. [2] The second research design was completed at KU Leuven, Faculty of Architecture, Campus Sint-Lucas Ghent (KUL). The course structure of this faculty is firmly rooted in 150 years of design tradition. Compared to WdKA this curriculum design shows strong similarities with the course structure of the École des Beaux-Arts in the early 18th century. Similar to École des Beaux-Arts, the design studio is the core of this programme. In parallel to the design studio, supporting courses like mixed media, history and theory, management, building technology and exact sciences are scheduled. Accordingly, theory courses are frequently provided in class rather than in workshops.

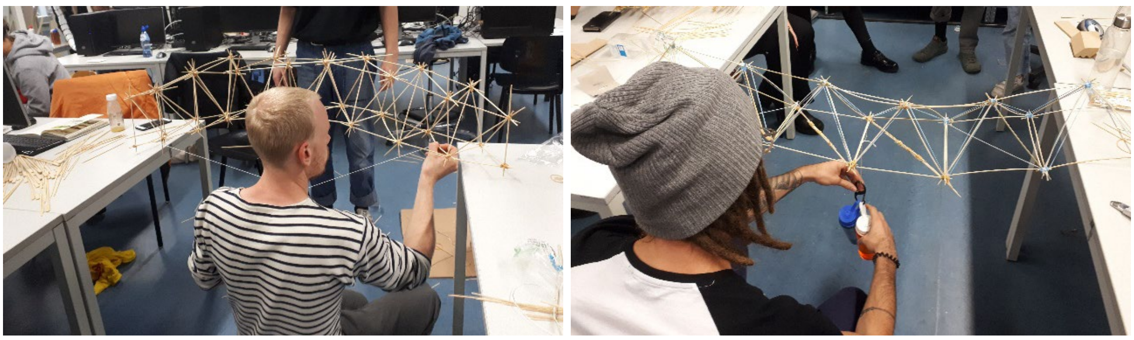

Figure 5. Examples of structure construction and testing at WdKA.

Table 1. Descriptives of research outcome for learning outcome scaling (Figure 3L.).

Descriptives

WdKA Ba01 - Group A

	Responses	Min	Max	Mean	Std. Dev.
Pre - Quiz A	7	-1,50	2,00	0,50	1,13
Mid - Quiz C	10	-0,40	2,20	1,06	0,88
Post - Quiz B	9	-0,50	3,00	1,54	1,05
Effect Size Pre-Post	1,33				

Descriptives

WdKA Ba01 - Group B

	Responses	Min	Max	Mean	Std. Dev.
Pre - Quiz B	8	-0,70	0,60	0,75	0,40
Mid - Quiz C	6	-0,70	0,80	0,43	0,56
Post - Quiz A	6	0,80	2,80	1,82	0,68
Avg. Std. Dev.					0,78
Effect Size Pre-Post	1,37				

Table 2. Descriptives of research outcome for learning situation design comparison (Figure 3R.).

Descriptives

KUL Ba02 - Group A

	Responses	Min	Max	Mean	Std. Dev.
Pre - Quiz A	25	-0,70	2,00	0,43	0,86
Mid - Quiz C	30	-0,70	2,80	0,92	0,91
Post - Quiz B	18	-0,70	2,80	1,82	0,91
Effect Size Pre-Post	1,58				

Descriptives

KUL Ba02 - Group B

	Responses	Min	Max	Mean	Std. Dev.
Pre - Quiz A	21	-1,50	2,00	0,43	0,96
Mid - Quiz C	14	-0,60	2,00	0,95	0,71
Post - Quiz B	22	-0,60	2,20	1,58	0,94
Avg. Std. Dev.					0,88
Effect Size Pre-Post	1,30				

In order to calculate the learning improvement per student, a combination of the quiz answers and the scale of sureness (1-10) was used. When a student answered the question with a right answer, the scale of sureness was divided by 10 and used as a score (form 0.1 to 1). When a student answered the question with a wrong answer, the scale of sureness was divided by -10 and used as a score (from -0.1 to -1). Based on these values, the quiz scores of the student was calculated by the sum of the scores (range -3 to 3). Next, the mean and standard deviation of each quiz was calculated to visualize learning improvement per interaction of the learning situation. Finally, the effect sizes using the results of the pre- and the post-test were calculated.

4 DISCUSSION

Each learning situation as presented in Figure 1 aims at different kinds of understanding, using a different sequence of interactions, resulting in different types of knowledge. In order to test each learning situation effectively, with each interaction, different types of measuring instruments should be applied. However, with the intention to compare the learning situations as presented, using a between-subject set-up, in both designs the same quiz questions are used.

In order to provide the measurement instruments with questions that relate to both deep understanding as well as conceptual understanding, an image of a visual representation of a structure was used in the question description. As the result of this visual aspect, it is assumed that both the result of learning through the interaction of activity as well as the interaction of transmission is tested. Learners that learned through the interaction of activity should be able to project the visual representations on earlier experiences, and learners that learned through the interaction of transmission should be able to revert to earlier examples introduced. However, by using visual representations, two errors can occur. Firstly, by using a representation, each participant might interpret the image differently. Secondly, by using visual representations of structures, the concept is always related to a context. Consequently, conceptual understanding might not be represented as well as deep understanding. This effect might explain the effect size differences between group A and group B in Table 2.

Compared to the work of Hattie, in this study, the amount of participants is relatively low. In addition, the participants differ in academic background, learning approach, and learning environment. Based on these conditions, multiple effects can be addressed to cause the variance of effect sizes per case, and the divergence from the reference sizes as introduced in section 2.1. Firstly, the amount of participants (Responses) involved in the studies as described in Table 1 and Table 2 vary strongly per case. In these cases, the higher the number of participants involved, the less variance in effect size is calculated. For example, in smaller groups with a similar background, effects like a shared learning approach can influence the effect size significantly. The relatively high but consistent outcome of the studies as presented in Table 1A, 1B, and 2B is likely to be addressed to this cause. As discussed by various scholars (Rømer, 2018; Snook et al., 2011), the quantitative research approach of Hattie introduce various issues. Firstly, by using effect sizes based on averages of quantitative data, social effects, background, and context effects, related to the courses discussed are ruled out. Secondly, the effect sizes only include knowledge types that can be measured quantitatively, and therefore favors surface and deep understanding over conceptual understanding. This effect might explain the difference in effect size as discussed in group A and B in Figure 2. Although the learning situation design is more likely to align with learning approaches as formed by learners of generation Y and Z, conceptual understanding might be measured less effectively, resulting in a lower effect size overall.

The evaluation of the measurement instruments has shown that it is difficult to design appropriate quiz questions to test conceptual and deep understanding of the student with a low chance of misinterpretation as seemingly comparable questions were answered with different scores by the same students.

5 CONCLUSIONS

In this study two learning situation designs are introduced and tested for effectiveness. In order to compare the results of this study to existing data, the effect size as introduced by Hattie in Visible Learning is used. Based on this score, for this study four effect sizes are used for reference: Feedback (0.75), Prior Achievement (0.65), Problem Solving Teaching (0.61), Student-centered teaching (0.54). In addition, Hattie adopts a minimum score of 0.4 for learning approaches to be relevant.

Based on the reference effect size, the effect size of the learning situations as introduced in this study are significantly higher (1.33, 1.37, 1.58, and 1.30). Based on the minimum effect size as adopted by Hattie, each of the learning designs is relevant. This outcome is supported by the student survey in which a preference for group learning, and learning through experimentation and trial-and-error was expressed. In addition, compared to the references each of the effect sizes as obtained in this study are higher. This difference might suggest that the effect sizes introduced by Hattie do not necessary apply to all learners. Based on social effects, background, and context effects, a specific learning approach might fit one learner better than another.

In the survey, the participants indicated to appreciate to learn in groups, and to learn trough experimentation and trial and error. In addition, the participants criticized the minimum of explicit introduction and feedback. Although this outcome confirms learning preferences as associated with learners from generation Y and Z, the outcome is not confirmed by the effect sizes as measured. In the product-oriented learning situation (effect size 1.30) the obtained score was lower compare to the process-oriented learning situation (effect size 1.58). This difference in outcome, might suggest that knowledge obtained through making was not measured effectively through the instruments used.

Based on the study outcome, both the learning situation designs as introduced are effective in the support of learning preferences assigned to generation Y and Z. However, based on the characteristics of the used measurement instruments, no recommendations of learning situation design can be made with regard to learning aims and learning context. Therefore, in following studies, the design of measurement instrument should be further developed. In addition, learning success as presented in this study do not necessarily apply to other groups or groups in years to come. There is a need for a continuous monitoring and adaptation of learning situation design to the learners addressed.

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