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Promoting best practice design intent in 3D CAD for engineers through a task analysis

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Abstract: Assessment encompasses a range of methods and techniques. At the University of Limerick, Ireland, it is an affirmed obligation to facilitate timely and useful feedback for both formative (for learning) and summative (of learning) assessment. However, the effectiveness of this feedback has raised concern and has a wide-ranging review of research findings. This paper presents research findings to build a picture of the extent to which the impact of feedback as a constructivist paradigm of teaching and learning can promote best practice design intent in 3D CAD Modelling. The resulting data set, comprised of 114 higher education students, is used to discuss the impact of assessment and feedback, comparing semesters Spring 2011/12 and Spring 2012/13. The 2012/13 cohort received formative assessment feedback from a task analysis. This evidenced an upsurge in understanding in best practice design intent in 3D CAD parametric modelling, supported by an effect size of 0.534.

Keywords: *Design intent, effect size, formative assessment, task analysis, 3D CAD modelling.*

I. INTRODUCTION

PT4424, 3D CAD Modelling, learning outcomes set out to develop student's application of effective parametric model building techniques, in the context of design, thereby building an understanding of design intent, creation of comprehensive product models and specifications in the context of the total development of a product, and comprehensively document designs generated from feature based models. In addition, and the focus of this paper, students must be able to apply the design process to solving a design problem using SolidWorks and explain their design solution, and demonstrate an appreciation of the importance of 3D parametric modelling in the contemporary design process. Constructive alignment ensured learning outcomes and assessment were associated. This was further promoted through the facilitation of feedback for the 2012/13 cohort.

Providing students with timely feedback is not the underpinning goal in higher education. Feedback has the implications for improving student's quality of work and developing an understanding for lifelong learning. Formative assessment aims to scaffold student's critical thinking and evaluative skills thus *"students have to be able to judge the quality of what they are producing and be able to regulate what they are doing during the doing of it"* (Sadler, 1989, p. 121). A focus on assessment can often lead to instrumentally motivated students who focus on marks rather than the value of the feedback (Bailey, 2010). This could consequently result in no feed forward for further learning and assessment as highlighted by Hounsell et al (2008) (Fig I). Hounsell's feedback loop promotes a student-centred constructivist paradigm of teaching and learning; student's understanding and expectations of assessment is evident, student's experience and awareness of feedback is facilitated and the idioms used in the feedback are clarified if required (Hounsell et al, 2008).

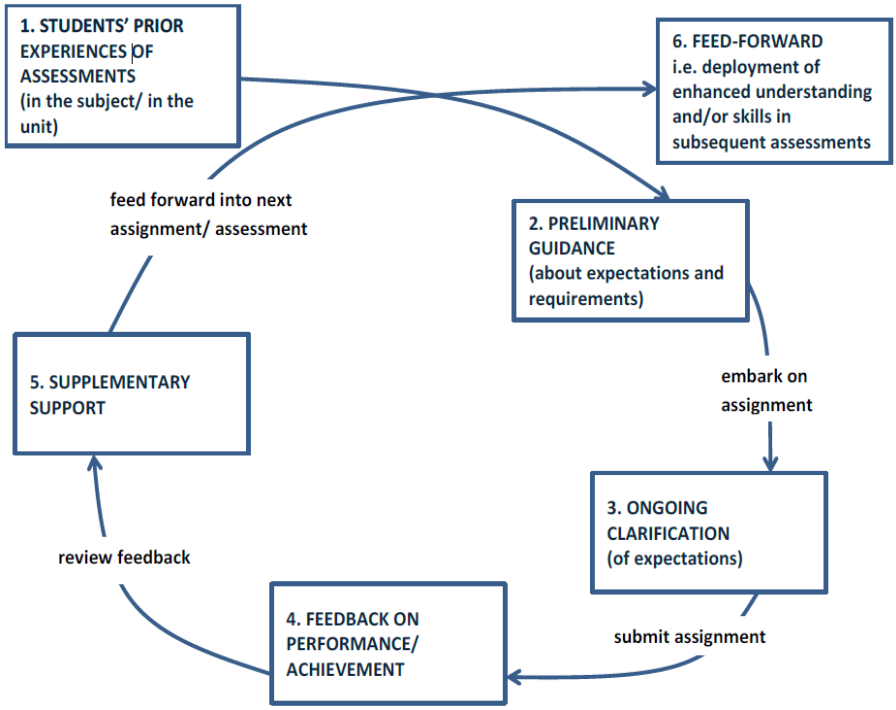


Figure I: Guidance and feedback loop – main steps (Hounsell et al, 2008)

II. METHOD

Students learning outcomes (Table I) were assessed in Spring 2011/12 through summative assessment, in contrast to PT4424 Spring 2012/13 formative and summative assessment (Table II). Hounsell's guidance and feedback loop was applied for the 2012 cohort's coursework assessment. At the end of Spring 2012/13 semester students were surveyed to determine the impact of the changes in relation to feedback during the 2012/13 module. The change in assessment was developed in relation to constructive alignment (Fig II). The intention of well-constructed learning outcomes enabling students to learn more effectively is evidenced in the literature (Biggs 2003, Rust et al 2003). However, there is an on-going concern that learning outcomes can also reduce student's critical thinking ability, due to a focus on assessment (Mc Mahon and Thakore, 2006). Thus, this study set out to investigate if and how outcomes can be used to foster critical thinking in 3D CAD Modelling. This critical thinking required students to apply synthesis and evaluation through their coursework, via a task analysis, along with the module leader's feedback via Hounsell's guidance and feedback loop.

Table I: PT4424 Learning outcomes

Learning outcomes; By the end of the module students will be able to:
1. Construct and edit part files using the SolidWorks parametric modeller.
2. Construct assembly files from created part files.
3. Demonstrate an ability to capture and implement design intent in product design.
4. Generate fully dimensioned and annotated working drawings for created parts and assemblies.
5. Develop exploded and cutaway assembly configurations for design documentation.
6. Apply the design process to solving a design problem using SolidWorks and explain their design solution.
7. Use the SolidWorks Toolbox library of fasteners and components.
8. Create and use document templates for part, assembly and drawing documents.
9. Produce photorealistic product renderings and animations.
10. Demonstrate an appreciation of the importance of 3D parametric modelling in the contemporary design process.

Table II: Overview of PT4424 2011/12 and 2012/13

MODULE	SEM/ YEAR	LEVEL / NO. OF STUDENTS	DELIVERY STRATEGY	ASSESSMENT
PT4424 (3D CAD Modelling)	Spring 2011/12	UG 2nd yr / 36, PG / 20, Co-op 2, Erasmus 1	2 hr interactive lecture. 2 hr lab. Educator-student interaction. Two-way communication. Educator-student questions. Shared responsibility for active learning. Small group, problem-solving activities. Variety of supporting media. Limited note taking required (students have copies of lecture notes).	Coursework design project Exam
PT4424 (3D CAD Modelling)	Spring 2012/13	UG 2nd yr / 30, PG / 20, Co-op 4, Erasmus 1	2 hr interactive lecture 2 hr lab 1hr Peer Supported Learning Groupx3 Educator-student interaction. Two-way communication. Educator-student questions. Shared responsibility for active learning. Small group, problem-solving activities. Variety of supporting media. Limited note taking required (students have copies of lecture notes).	Task analysis design product Coursework design project Exam

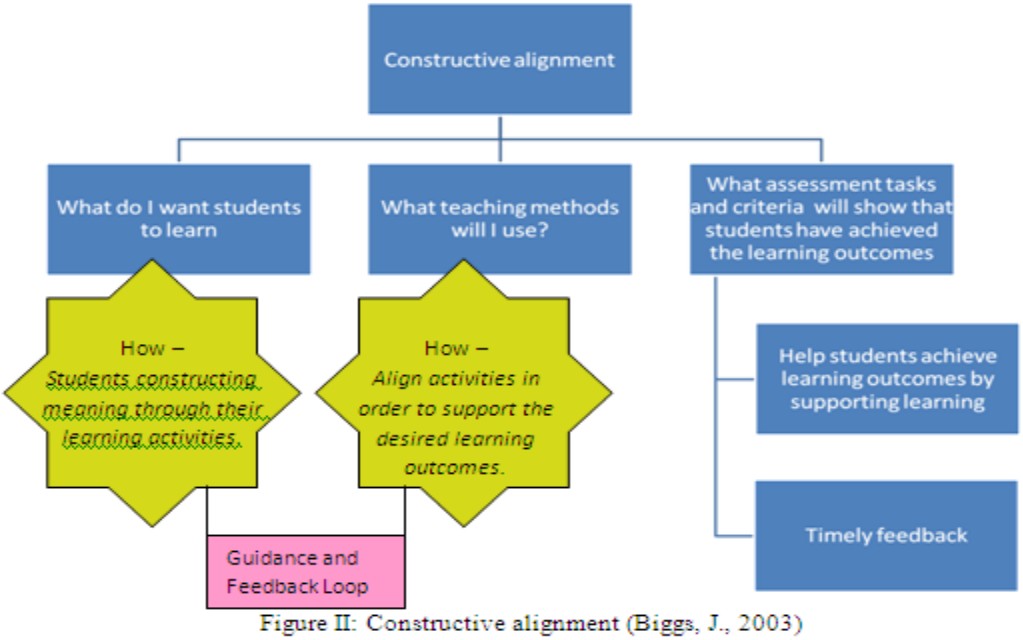


Figure II: Constructive alignment (Biggs, J., 2003)

The formative assessment in Spring 2012/13 involved a task analysis of students design intent for parametric modelling of a product (Fig III; Table III). This task analysis did not form part of the student's final grade or mark. It was used to provide constructive feedback to improve students learning and understanding of 3D CAD Modelling. The task analysis served as preliminary guidance and on-going clarification for the assessment (Hounsell, 2008). The feedback from the task analysis helped scaffold students as they embarked on the coursework. The peer supported learning group and laboratory sessions provided supplementary support to this feedback.

Table III: PT4424 Coursework outline abridged

Coursework:
1. Select the consumer product from the household product range in the file provided, or from a personal source.
2. Once your product is selected you must start planning your design intent. Create a task analysis for the design and manufacture for the production of the component. This is an essential element in the design intent and planning for parametric modelling. Task analysis is in the context of the design process for the product and design intent for SW modelling.

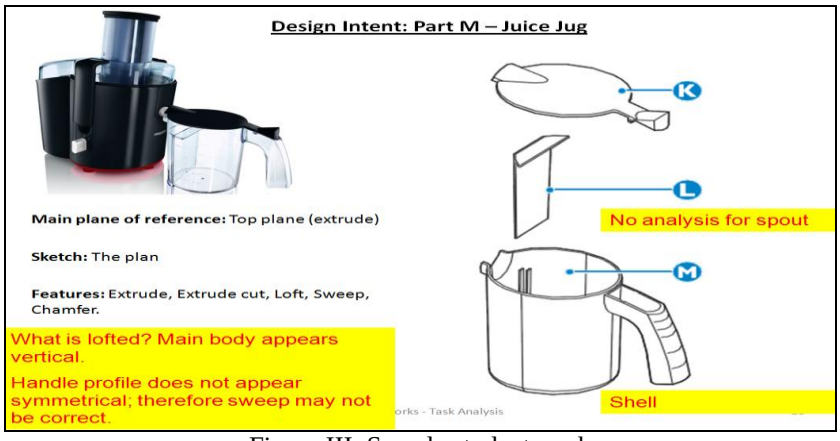


Figure III: Sample student work

In addition, as highlighted in the literature, effective feedback is 'timely' (Bailey & Garner, 2010). "A not uncommon fault, particularly within semester system, is that students only find out how well, or how badly, they have done when their assessed work is returned with a mark and comment at the end of the semester. By that time is it too late to take any remedial action." (Fry, H. et al, 2008, pg 121)

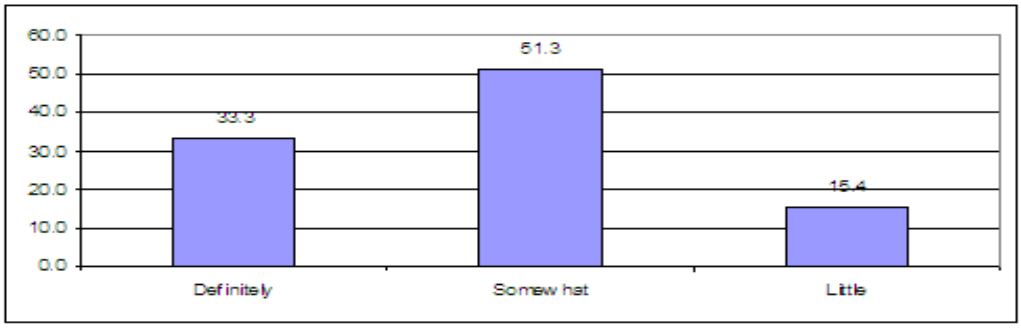
The return of this task analysis and feedback by the module leader was timely (week 6 of 13-week semester) and communicated by the module leader to individual student via email and a summary of all students feedback was uploaded to Sulis (Sulis is a set of software tools designed to help lecturers, tutors and students have spaces (web sites) for collaboration, communication, teaching and learning). The written feedback comments were clearly referenced in context or embodied on the various task analysis sheets (Figure 3), thus students were able to connect the specific elements of coursework the module leader was providing feedback for. In addition, opportunities for tutorial interactions between the module leader and the students were facilitated during 'open office' feedback time, peer supported learning sessions and laboratory time.

Whilst also maintaining the balance between the teacher's role of supporting and facilitating students' learning and that of assessing their achievement, this task analysis solely served the purpose of clarifying, supporting and facilitating students learning, thus as mentioned earlier no marking was allocated to this element of coursework. This is supported by the literature; *"One of the most important aspects of supporting student learning is the feedback that students receive on their work"* (Fry, H. et al, 2008, pg 121). In addition, though this task analysis was not awarded marking, 92.2% of students completed the task analysis, which is an extremely high proportion, demonstrating that the majority of students understood the benefits for the learning experience. Allocating marks for such task analysis could result in students focusing on assessment thus becoming instrumentally motivated, focusing on marks rather than the educational value (Higgins, R. et al, 2002; Bailey, 2010).

III. RESULTS

This formative assessment, (written responses noted (in yellow textbox) on students task analysis) (Fig III), provided students with more confidence and motivation to obtain a good grade. From an end of semester assessment and student feedback survey 84.6% (Graph I) of students reported that feedback (Table IV) made them more determined / motivated. Thus students were extrinsically motivated. One student commented "From the analysis I found out in advance how to draw. The feedback helped me find different ways to model the parts.

The feedback impacted on nearly everything I used. The feedback motivated me because I knew I could achieve it. However it would be good to get a grade for this. The feedback, all problems were answered. It would be good to get feedback at the end to know where I went wrong" (PT4424 Student comment, Week 12 feedback survey).

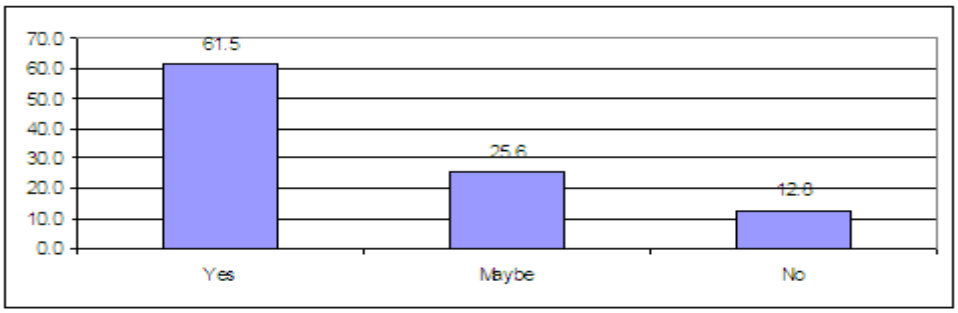


Graph I: Students more confidence and motivation (values as percentage)

Table IV: Feedback abridged

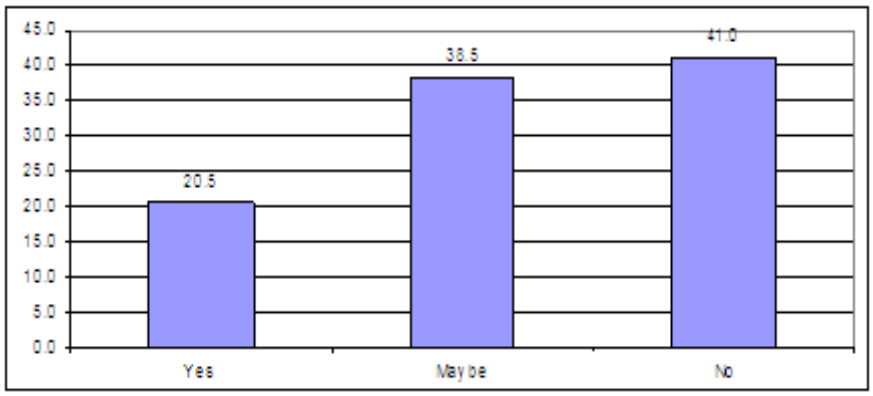
Feedback
Needs to greatly improve and incorporate advanced modeling
Excellent work! Small few bits need to be considered
Needs more advanced modelling and ensure detail is very detailed as parts appear very simple
Needs more advanced modelling and consideration of moving parts.
Needs to clarify parts and design intent not visible for main part!
Poor did not analyse in the context of each part and graphic. Few bits need clarification such as the basket!
Confusion between loft, sweep, extrude. Also watch symmetry of parts.
Need to use more advanced modeling, design intent for some parts not correct or not completed
Needs more advanced modelling. All parts not analysed.
Lacks advanced modelling. Many parts not explored in the analysis. Difficult to follow the analysis as it is not in context of supporting visuals for various parts.
Yes okay, few bits to improve; difficult to determine where featuring was referring to.

Intrinsic motivation was also addressed, 87.1% (Graph II) of students understood the benefits of the task analysis, highlighting that the feedback increased their learning and understanding of 3D CAD modelling. Student comments supporting this include; "Good idea to do the analysis and get feedback as it got you thinking of your project." (PT4424 Student, Week 12 feedback survey); "The analysis and feedback made me think a bit harder" (PT4424 Student, Week 12 feedback survey). The teaching assistant for this module also noted the difference between the 2011 and 2012 cohort; "They seemed to have a greater grasp of some of the advanced functions, and that's probably due to the fact that they had to start thinking about how they were going to build the parts. Most of the design intent was better to previous years and use of the programme was much better" (PT4424 Teaching Assistant).



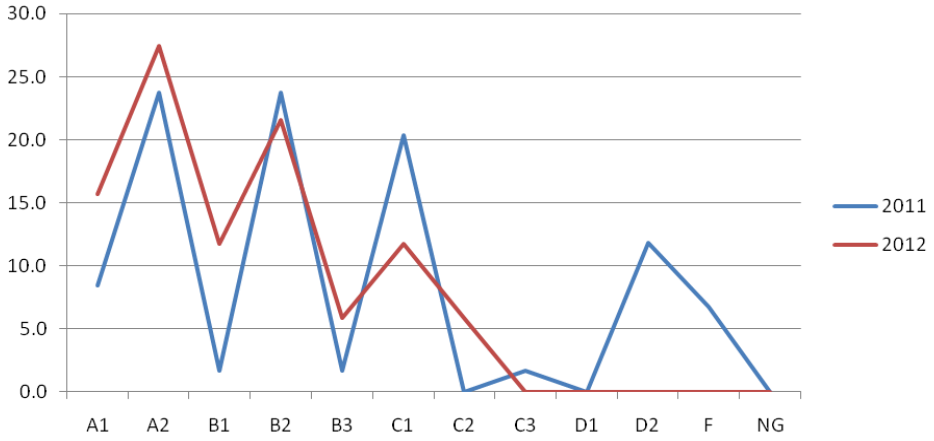
Graph II: Understand the benefits of task analysis (values as percentage).

This motivation in students learning through feedback and assessment was not instrumentally motivated; focusing on marks rather than the educational value of written comments. Students also expressed the appreciation for feedback; in the survey only 20.5% (Graph III) of students expressed that they would like to receive a grade rather than feedback. Student's comments include;
"I would like to get feedback on my final exam to see where I can improve / went wrong."
"I would like to know where I went wrong as well as getting a grade"
"It would be good to get feedback at the end to know where I went wrong."
"Very good thorough feedback. Definitely want feedback on exam and project."
"Feedback was good as it gave hints and tips on how to model your chosen product. I would want feedback if I was to do more 3D CAD modelling modules."



Graph III: Would you like to receive a grade rather than feedback (values as percentage).

From the summative assessment, comparing end of semester coursework grades for PT4424 2011 /12 cohort and PT4424 2012 cohort, the 2012/13 cohort demonstrated a higher percentile for higher grades (Graph IV). Thus, one can deduce that the impact of the formative assessment has improved students understanding of design intent for parametric modelling by instilling greater motivation and appreciation for best practice.



Graph 4: PT4424 Coursework grades (values as percentage).

Statistically measuring the magnitude of difference between the two groups is calculated using the effect size. An effect size above 0.4 is above average for educational research. The task analysis involved in this study was carried out to reinforce best practice design intent. The task analysis also served the function of feedback, giving students positive reinforcement toward improvement and clarifying goals. From this task analysis students demonstrated the ability to self-regulate their own learning, thus increase achievement. The effect size between the two groups in this study was 0.534, medium effect (Cohen, et al, 2011), which is equivalent to one grade leap (Hattie, 2011).

IV. CONCLUSION

The feedback has acted as a constructivist paradigm of teaching and learning, whereby students demonstrated improved learning achievement through design intent, a key fundamental for parametric modelling. This paradigm shift in assessment design to promote assessment for learning rather than of learning is demonstrated through student's improved learning achievement for best practice design intent. The implementation of the task analysis was facilitative for deep learning. Assessment in PT4424 is not about the reproduction of passive incremental knowledge; assessment is active and transformational. This is evident in student's final submission of coursework assessment where students demonstrated a 'deployment of enhanced understanding and skills' thus evidencing their ability to feed forward the feedback and guidance. This correlates with Black and Wiliam (1998) statement with respect to formative assessment; "with gains in learning 'among the largest ever reported for educational interventions" (Hounsell et al, 2008 p. 55).

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