IMPROVING ENGINEERING DRAWING SKILLS THROUGH CONCRETE LEARNING AND MINDSET THEORY

Paul Warrington[1], Sarah Junaid[1]

1 Department of Mechanical Engineering and Design, Aston University, UK

ABSTRACT

The engineering drawing skills for the Design-Build-Test (D-B-T) project in year 2 Mechanical Engineering and Product Design degrees at Aston University is introduced through regular practice exercises that are transferable to the project. However, analysis of the CAD assessment in the previous two cohorts (2015/16 and 2016/17) showed low performance and the associated engineering drawings for the D-B-T project was poor. The aim of this study was to address this disconnect by reviewing the CAD exercises and developing a more open growth mindset among the students. The program was developed with a two-pronged approach to include exercises that are more analogous to the D-B-T project with encouraged deliberate practice and introduce growth mindset theory and use of study strategies. Student mindsets will be captured at the end of the module through a short questionnaire. Thus far, the new intervention appears to yield better performance in CAD modelling and engineering drawings. However the study is on-going and therefore CAD assessment and the engineering drawings for the D-B-T in 2017-18 cohort will be compared to the previous two cohorts at the end of the academic year.

KEYWORDS

Deliberate practice, Mindset theory, technical skills, CDIO Standards: 3, 5, 8 (Integrated Curriculum, Design-Implement experiences, Active Learning).

INTRODUCTION

The CDIO framework (Conceive-Design-Implement-Operate) at Aston University has been used to develop professional skills while applying technical theory in team-based D-B-T (Design-Build-Test) projects. Four projects are carried out in year 1 and 2, each running through a 12-week semester. CAD skills (Computer Aided Design) and engineering drawing skills are required to strengthen the D-B elements of some projects and are fundamental to the skillsets required from mechanical engineering graduates. Currently, year two students are given CAD instruction, exercises and assessments designed to implement purposeful and systematic **deliberate practice (**Ericcson et al. 1993).

Deliberate practice requires purposeful regular practice of a skill to improve performance. CAD and engineering drawing skills serve as a good example of implementing deliberate practice in the teaching program. They require regular individual exercises and expert feedback as well as peer feedback to guide and improve performance. Individual CAD assessments during year 2 are based upon parts that are analogous to their D-B-T projects. The students are expected to see the relevance of the fundamental knowledge and skills acquired in their CAD sessions and therefore connect and apply these to their D-B-T project. However, it is evident that this is not the case. Individual CAD assessment scores are low, and CAD outputs for their D-B-T projects are poor. This possibly points toward a disassociation between perceived CAD skills and actual engineering drawing/design knowledge and skills required.

Furthermore there was a tendency for students to associate CAD skills with natural ability with some students exhibiting fixed mindsets, the inability to see skills, performance and intelligence as something that can be developed and improved (Dweck 2007). Based on these theories, it appears that improving teaching material and delivery for effective learning is only part of the solution. Encouraging a growth mindset may also be an important part of the solution that is conducive to student learning and essential for professional development.

AIM AND OBJECTIVES

The aim of the study is to create a more experiential learning experience (Kolb 1984) and imbue a growth mindset throughout their 12-week D-B-T project. The first objective is to embed deliberate practice through CAD engineering drawing practice and assessment into the D-B-T project itself and then give opportunity for iteration after feedback. This will be done by designing exercises that are more analogous to the D-B-T project (designing a pneumatic actuator and 3/2 valve) and providing expert and peer feedback through weekly CAD sessions for the first 8 weeks of the project. The second objective is to introduce deliberate practice and study strategy theory, which will be communicated within a **growth mindset** (Dweck 2007) framework in order to improve the process of learning. This will be done through weekly 30-minute interactive classroom delivery in the first 7 weeks of the project.

METHODOLOGY

Deliberate Practice CAD Exercises Before Intervention

Two-hour weekly CAD sessions were delivered over the first 8 weeks of the project. Theory and associated exercises teaching the principles of CAD modelling, engineering drawings and sub/general assemblies were carried out during the sessions. Two CAD assessments were carried out under exam conditions over 2 hours and feedback given before submission of the D-B-T project. The first CAD assessment was to reproduce an engineering drawing of a machined part by modelling the part and deriving the engineering drawing. The second CAD assessment was to assemble several parts provided and produce a General Arrangement drawing. The first and second CAD assessments were not associated to the project directly and did not utilise all features that they would need for their own project. CAD assessment data from two cohorts from 2015-16 and 2016-17 were analysed where cases of no submissions were excluded from the analysis (both n = 109).

Deliberate Practice CAD Exercises After Intervention

For the new intervention, the deliberate practice exercises were designed for students to 3D CAD model piece-parts that are later used in exercises where they are required to reproduce the exemplar piece-part engineering detail drawings that they are given to work from (thereby simultaneously exposing them to engineering drawing ‘best practice’ and giving opportunity to use deliberate practice with immediate implicit feedback). Furthermore, these same modelled piece-parts were required to be assembled and used to produce Sub-Assembly and General Arrangement drawings of a double-acting piston pump. CAD modelling guideline theory, engineering drawing guideline theory and British Standard requirements for engineering drawings were also delivered through these weekly sessions. The exemplar double acting piston pump utilises all functions that students would need to include in their D-B-T project (designing a pneumatic actuator and 3/2 valve). For example, functions such as concentric locating and fastening required at a piston/rod joint, correct O-ring groove design and sizing to ensure both static and dynamic sealing at part interfaces, and correct model detailing of injection moulded piece-parts are all demonstrated in order to demonstrate acquisition of Engineering drawing skills, Second year students from 2017-18 (n = 130) are required to submit an individual CAD assessment of a detailed engineering drawing and a General Arrangement drawing of the double acting piston pump that they have previously seen during tutorial/practice sessions and which is directly analogous to the actual D-B-T project. The parts are familiar, as they have previously been individually modelled from deliberate practice tutorial exercises carried out over the first 8 weeks. Assessment and feedback for the CAD were given before the final project submission. The detailed engineering drawings, Sub-Assemblies and General Arrangement drawings for the pneumatic actuator and 3/2 valve design will also be submitted at the end of week 9 towards the end of the project for manufacturing.

Mindset Theory and Study Skills

For the new intervention a proportion of the project contact time was dedicated to delivering professional development activities and theory. The theory behind growth versus fixed mindsets (Dweck 2007), deliberate practice (Ericcson et al. 1993), study strategies and time management and productivity tools, which are linked to achieving skills competence and improving performance (Nandagopal & Ericsson 2012) were taught with associated tasks. For example, to demonstrate the process of testing study strategies to achieve a goal, the cohort was asked to "Note an activity or goal you set and a strategy used to get there" and were then asked to reflect on whether they needed to change their strategy at any point when they were not achieving, The cohort was then asked to share their experience with their team. These personal development sessions were delivered over 5 sessions in the first 7 weeks and were prepared using the literature for evidence-based learning. The delivery of these sessions was in parallel with technical theory and deliberate practice CAD sessions over the 12-week program (figure 1). Organization and time management tools were given for students to use in their own D-B-T projects however there were no assessments or compulsory exercises relating to these sessions. For example, the Eisenhower decision matrix tool was demonstrated as a workload management tool that students could use to prioritize their tasks and work more efficiently (Figure 2).

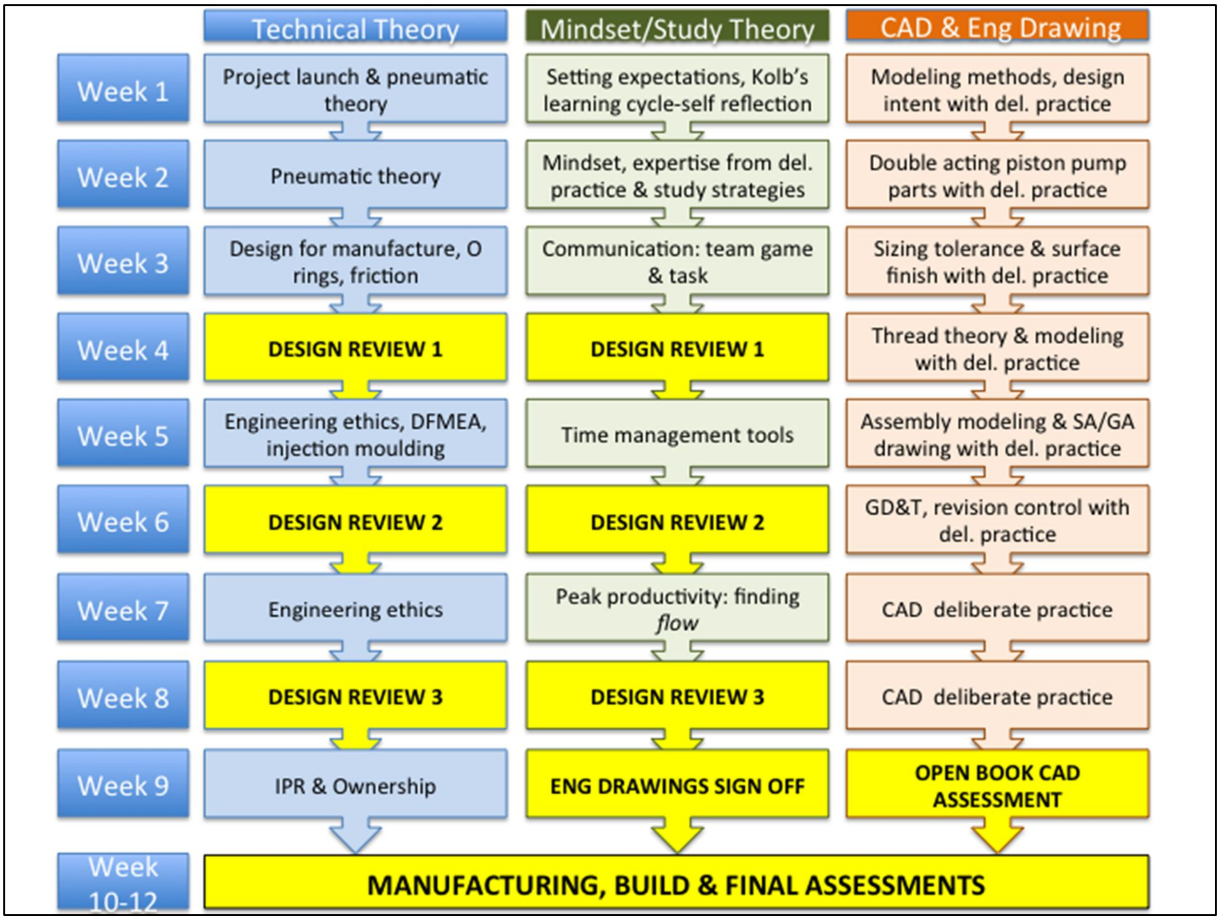

Figure 1. Module map: mindset theory and study skills delivery in parallel with technical theory and deliberate practice CAD sessions over the 12-week module

	URGENT	NOT URGENT
IMPORTANT	**DO!** *E.g. impending work deadline, paying a bill* Should take priority but not consume most of your time. Reality: almost all time dedicated	**DO!** *E.g. CVs, job applications, planning ahead* Should be **most of your workload** before tasks become URGENT. Reality: very little focus in planning effectively
NOT IMPORTANT	**DELEGATE!** *E.g. club/society commitment, helping at an event* Should spend little time Reality: due to urgency, spend too long on these tasks	**RESTRICT or DON'T DO** *E.g. club/society commitment, recreational trip/activity* Should spend little time Reality: can often drain your time unexpectedly

Figure 2. Eisenhower decision matrix used as an example of a time management tool with explanations delivered in mini-lecture form.

The purpose was to develop an understanding of these behavioral and mindset theories in order for students to implement some of the tools given to develop the CAD skills for the project and improve general academic performance. A survey link was sent at the end of the module to capture student mindsets. The survey contains 3 questions using a 6 Likert Scale to assess growth versus fixed mindset (Table 1), which has been developed and validated through evidence-based research by researchers in Project for Education Research and Scales (PERTS 2018).

Table 1: PERTS growth mindset assessment (PERT 2018)

	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
Q1: You can learn new things, but you can't really change your basic intelligence.	o	o	o	o	o	o
Q2: Your intelligence is something about you that you can't change very much.	o	o	o	o	o	o
Q3: You have a certain amount of intelligence and you really can't do much to change it.	o	o	o	o	o	o

Assessment and Performance of CAD after Deliberate Practice and Intervention

For the new intervention, the CAD assessment was designed as an open book 'exam' with an extended 11-hour submission window. The aim for changing the assessment delivery to open book was to encourage good practice and offer the opportunity of peer learning whilst delivering drawings to the standard demonstrated though the CAD sessions. Also, the extended submission window offered students a further opportunity to practice and reflect upon the assignment task. Students submit detailed engineering drawings and Sub-Assembly of a component of the double acting piston pump system that has been used throughout the CAD tutorial sessions.

The CAD submissions for the pneumatic actuator and 3/2 valve (D-B-T project) will be reviewed after the module for this study only to assess performance and will not be part of the module assessment. The performance distribution between the CAD assessment within a cohort and year-on-year comparison (between cohorts) will be compared using paired and unpaired t-tests respectively.

PRELIMINARY RESULTS

CAD Performance before Intervention

The two cohorts before the intervention showed a significant decrease in performance between the first CAD assessment and the second ($p < 0.05$) (Figure 3). Comparing year-on-year, the first CAD assessment shows a significant drop in performance in the latter cohort from an average (± SD) of 57.4 ± 24.6 % to 51.0 ± 22.0 % ($p < 0.05$). The second CAD assessment showed no significant difference between the two cohorts showing a drop in performance in 2015/16 and 2016/17 with averages of 45.1 ± 20.5 % and 45.6 ± 19.1 % respectively.

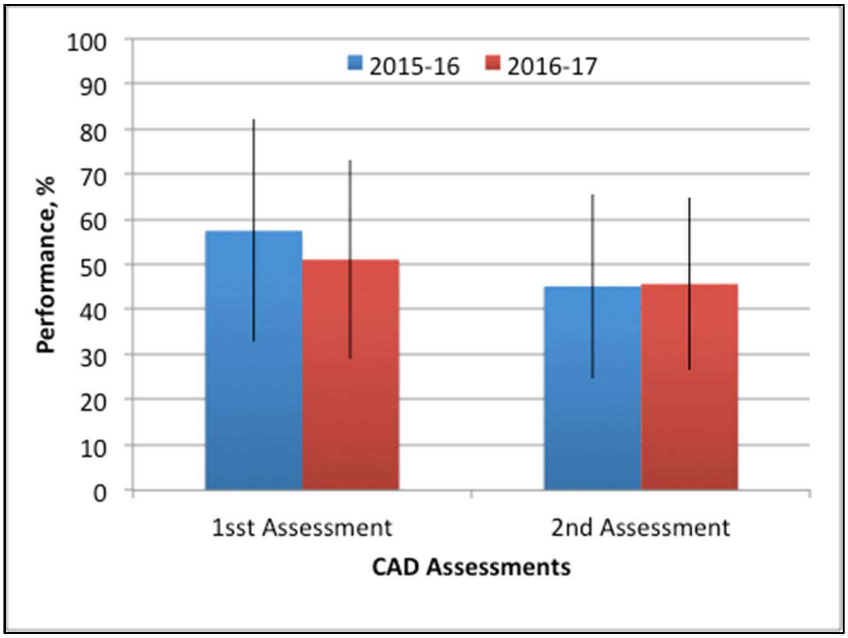

Figure 3. Performance between CAD assessments significantly decreased within a cohort (p <0.05). Year-on-year comparison showed a marginal drop in 1st assessment and no change in the 2nd assessment.

CAD Performance after New Intervention

The CAD assessment and the CAD drawings for the project will be assessed at the end of the second academic term in May 2018. Anecdotally the CAD drawings for the D-B-T project (pneumatic actuator and 3/2 valve) after the intervention demonstrated a considerable improvement in terms of drawing quality and compliance to guidelines given.

Student Mindsets

The mindset survey outcomes will be captured at the end of the module to capture the mindsets of students and whether they identify with a fixed or growth mindset. These will be reported at the annual CDIO conference 2018.

DISCUSSION

Performance analysis of the previous two cohorts before the intervention indicates that deliberate practice undertaken does not translate to improved CAD performance, with the 2nd CAD assessments averaging approximately 45 % (Figure 3). Relevance needs to be concrete, requiring exercises that were directly relevant to the project with regular feedback. Furthermore anecdotal evidence highlighted poor performing students with fixed mindsets, where they perceived their CAD abilities as limited and fixed. This mindset was perpetuated by a lack of motivation and therefore a lack of practice.

The direct impact of attitude and perception of skills (fixed/growth mindset) to behaviour and performance is evident (Claro et al. 2016; Dweck 2007). Thus a two-pronged approach was used in this study: developing a learning structure through a growth mindset framework that emphasised regular deliberate practice through weekly CAD sessions and CAD exercises where expert feedback was at hand from their instructors. The practice exercises were designed to satisfy the requirements for deliberate practice and were analogous to the D-B-T project (pneumatic actuator and 3/2 valve). Anecdotal evidence with the new intervention to date demonstrates a considerable improvement to the quality of CAD engineering drawings and compliance to guidelines given. However performance data for the new intervention will be assessed at the end of the 2017-18 module in May 2018 and presented at the annual CDIO conference in June 2018.

There were several drawbacks to the study; firstly the mindset of the student cohort was not captured at the start of the module. This is needed to effectively assess whether the two-pronged approach of delivering open mindset theory and deliberate practice sessions translated to changing mindsets and improving skills competence. However, comparison of student performance from the previous cohorts used to compare the new intervention does not show significant differences in average performance from previous CDIO projects. Secondly the significant change in assessment delivery from a 2-hour exam to an open book exam with an extended deadline window may have impacted on the performance and behaviour of students. Indeed exam conditions can negatively affect some students that do not perform well under high-pressure situations that time-limited exams can create. Thirdly, the change in teaching delivery and other module management changes means that there are several confounding factors to this study that will make conclusions tentative. However, these changes are in line with the university's learning and teaching policy to implement improvements to the module from student and staff feedback carried out every year. Finally, this study observes the performance of one cohort after the new intervention and will therefore require two or more cohorts to build a more comprehensive study of the project aim.

CONCLUSION

The authors believe deliberate practice in order to improve a skill must be understood by students and actively implemented to be directly relevant to the immediate project goal and couched within a growth mindset approach in order to encouraging successful skills development and performance improvement. This study used CAD modelling and engineering drawing skills as an example to demonstrate a new approach to improving the learning of a skill. The study is on going however, to date, anecdotal evidence implies an improvement in CAD engineering drawing standards based on the two-pronged approach of delivering open mindset theories and deliberate practice sessions. Furthermore, a follow up study will require a comparison of mindsets before and after intervention to prove it's effective use.

REFERENCES

Claro, S., Pauneske, D., Dweck, C.S. (2016). Growth mindset tempers the effects of poverty on academic achievement. PNAS, 113 (31): 8664-8668.

Dweck, C.S. (2007) *Mindset - The new psychology for success*: Ballantine Books.

Ericsson, K. A., Krampe, R. Th., Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100 (3): 363-406.

Kolb, D. A. (1984) *Experiential Learning*, Englewood Cliffs: Prentice Hall.

Nandagopal, K. & Ericsson, K. A. (2012). An expert performance approach to the study of individual differences in self-regulated learning activities in upper level college students. Learning and Individual Differences, 22: 597-609.

PERTS, Project for Education Research and Scales. (2018). *Growth Mindset Assessment.* Available: https://www.perts.net. Last accessed March 2018.

BIOGRAPHICAL INFORMATION

Paul Warrington is a lecturer in Mechanical Engineering and Design at Aston University, UK. His research interests include the engineering design of intelligent automation applied to special purpose manufacturing equipment, precision machine design, engineered product design, engineering design methodologies and creative design thinking. He is the chair of the group's Industrial Advisory Board with an active interest in applying industrial rigor to student project based learning activities.

Sarah Junaid Ph.D. is a lecturer in Mechanical Engineering and Design at Aston University, UK. Her pedagogical research interests include student learning, engineering ethics and professional skills development. She is the head of the Biomedical Engineering research group with an interest in biomechanical testing and computational modelling within orthopedics.

Corresponding author

Dr. Sarah Junaid
Aston University
Engineering and Applied Sciences
Birmingham
B4 7ET
UK
++44 121 204 4177
s.junaid@aston.ac.uk