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The Use of Engineering Sketching and Journaling to Foster Deep Understanding of Construction: an Exploratory Study

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Abstract

In today's teaching environment where students' main focus is on getting a high mark for a class, deep understanding has taken a backseat. Being able to answer as many exam preparation questions as possible and fulfilling all the criteria on an assignment will guarantee success. "I deserve a higher mark because I worked hard in this class," are the arguments one hears after the final marks are published. How about understanding the new material presented in the class? Engineering sketching and journaling have been hailed by experienced engineers as tools to enhance thinking and communication. The authors of the paper report about their utilization as teaching tools to foster deep understanding in a course on construction equipment and methods. While topics like equipments economics, power transmission and safety benefit from graphing in two-axis coordinate systems, understanding the best path of a backhoe bucket during a trenching operation is impossible to describe in words. Of course, understanding has several components: a) WHY do we use a backhoe excavator and not a trencher, b) WHAT are the possible three link motion paths and their related force vectors, c) HOW can the operator control the path of the bucket, and d) WHAT-IF there are utilities buried in the ground?

It will be shown how the four learning types, according to Kolb, respond to the challenges of expressing their understanding. This paper also presents a correlation analysis between the four learner types, sketching, journal and students' examination marks.

Keywords: Engineering Sketching, Journaling, Understanding, Learning, Construction

Introduction

Two major educational tools, journaling and sketching, offer many opportunities for students to reach higher levels of understanding while acquiring skills that will be critical in their professional future. While sketching was once hailed as standard practice in the engineering profession it has succumbed to the more "efficient" digital drafting software available as a means to represent engineering designs (Sobek 2002).

Was it really fitting to replace sketching with computer-aided-drafting-drawing (CADD)? According to Tversky (2000), sketches were and are still used in many different areas for efficient communication especially in engineering. In fact, Jacobs and Brown (2004) argue that engineering drawings are an essential part of the engineering profession and that every engineer will deal with some form of graphical representation almost daily. Glegg (in Kardos 1997) summarized the situation when he wrote "Words are not the natural language of engineers. Drawings are their prose, mathematics their grammar and differential equations their poetry". Sketches provide an effective means to externalise ideas, turn internal thoughts public and unlike the written language are able to take advantage of visuospatial ideas, drawing on elements and spatial relations on paper. Arguably, this makes comprehension and inference making easier compared to a more subjective medium such as formal language (Tversky 2000).

Another excellent channel to express thoughts and ideas for oneself or others is the written journal. However, journaling has never found a real foothold in engineering despite its additional value to offer students the opportunity to practice writing, a recognized weak skill of graduating students. Journaling for a class should not be equated with creating a simple diary of what happened during the semester. Its real power lies in its flexibility to define leading questions that a student would have to address similar to creating an engineering sketch. Indeed, the importance of writing cannot be denied. A growing number of literature associates writing with the learning process (Hyland 2002; Zimmerman 1999; Tynjala and Mason 2001). Furthermore, writing is not just a linear sequence of activities but rather one with sub processes such as planning, monitoring, drafting, revising as well as editing (Southavilay et al. 2010) and differences do occur depending on both the writer's style and the nature of the writing task. In many ways, sketching and journaling represent two different avenues of articulating knowledge and understanding of a subject, each one offering a unique form of expression.

This paper argues that both sketching and journaling used in engineering education offer critical traits that facilitate the students' deep understanding of simple as well as complex material. It is believed that sketching adds a unique level to understanding beyond what journals can do.

This paper presents the empirical results of a study with students in a third semester course called Engineering Construction (Semester 2 -2011). Firstly, the students' learning types are established using the LTM survey tool that is based on Kolb's four learning styles. It then proceeds by exploring understanding of construction materials by means of assessing the quality of students' sketches and written journals. In particular, differences in the use of these two communication tools are sought considering each student's learning style. The 350 students of were asked to sign a consent form expressing their willingness to participate in this study by letting the research team use their performance data for analysis without using their names. One hundred and sixty students signed the form.

Journaling as an Effective Educational Tool for Engineers

There are many different forms of journals, the reflective type being most useful to education. They require students to reflect upon a certain idea or concept and to pen down thoughts with the intention of discussing, elaborating or applying an idea (Sobek 2002). For example, the student could be prompted with the following questions, 'What is the most interesting thing you have learned this week and why?', 'How can you apply the concept you have learned in class?' or perhaps 'Did you agree with the argument presented in class and why or why not?' Another form of journal is the dialog journal where the student is required to submit a journal on a weekly basis and their understanding accessed via feedback provided by the instructor tasked to mark them.

There are many benefits of journaling. Sobek (2002) argue that it not only helps students to be more expressive but also aids their thought process. Back in 1991, Zacharias found that this thought process involves many critical learning skills such as: a) comparing, b) contrasting, c) summarizing, d) observing, e) classifying, f) interpreting, g) hypothesizing, h) critiquing, i) looking for assumptions, k) imagining, l) collecting/organizing data, m) applying facts/principles, and n) decision-making. Additionally, teachers can also use journals as a gauge of a student's understanding and examine how they are processing information (Sobek 2002).

Bloom's TAXONOMY

There are six hierarchies based on Bloom's taxonomy depicted in Figure 1. Bloom's most basic level of thinking is remembering which simply refers to the ability to recall from memory, for example this could be a person's name or phone number. This is then followed by understanding or comprehension which means the ability to construct meaning from oral, written or graphic messages. This can be demonstrated through several key actions such as identifying, locating, indicating, explaining, generalizing, inferring, paraphrasing, predicting or explaining. The third level is applying which refers to how someone uses what is learned to solve authentic or novel problems. Examples of such trades include being able to construct, categorize, compare, contrast, employ, manipulate, modify, predict, relate, show and solve issues. Analysing is the next level in the hierarchy and involves structuring, comparing, differentiating, distinguishing, examining and breaking down problems into various components and showing how each of these parts relates to each other. A typical example would be trouble shooting the faults of a piece of equipment. At this level, students are also able to identify clues from which inferences may be drawn and indicate what their relationships are. The next level is evaluating which involves making judgments about relevance and importance of information based on criteria and standards via checking and serious critiquing. An example of this would be in selecting the most effective solution. Finally, at the top of the hierarchy we have creating and innovating by putting different elements together in order to form a new coherent and functional entity.

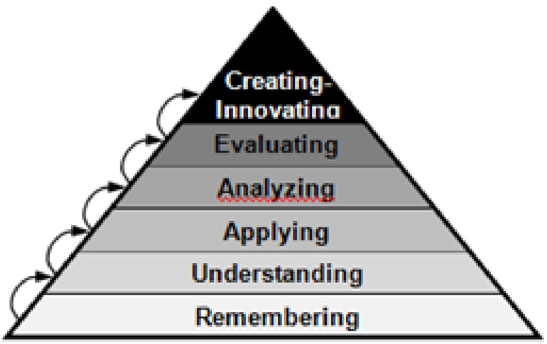


Figure 1: Bloom's Taxonomy

Measuring Students' Learning Preferences For the discussed experiment, the Kolb model was used to assess the learning preference of the 132 volunteering students. It consists of two main dimensions: 1) 'perception' (how things are taken in) and 2) 'processing' (how are things internalised). The first axis is divided into concrete and abstract while the second axis separates people into those who learn concretely by seeing, hearing or touching and those who prefer to perceive things abstractly through ideas, concepts or symbols.

Another dimension 'processing' is represented as being active on one extreme and reflective on the other end. Based on these two domains, four learner types are identified represented by each type as depicted in Figure 2.

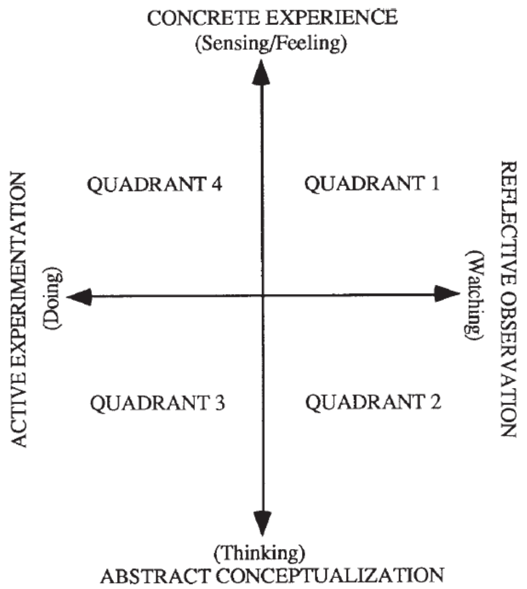


Figure 2: Kolb's four learning preferences

The four learning styles by Kolb has been characterised by a favourite question each, representing the pattern or trend in learning new concepts; Type1: Why? Type 2: What? Type 3: How? Type 4: What if?

Type 1

Students who are dominant in this type are interested on establishing a feel for the subject matter. They need to be able to answer the question of why am I learning this? And understand the relevance of the subject taught and how it may be applicable in the future.

Type 2

Those whose preferred learning style is in this type are keen on knowing what is presented and information transfer is an essential part of the function of educators here.

Type 3

Learners in type 3 are 'doers' and enjoy processing information by applying it. They not only like doing homework but also prefer to toss the manual aside and embrace the computer program by themselves. Hence, providing students with exposure both inside and outside of the classroom would be very beneficial.

Type 4

This type is about self-discovery where students would continuously find an opportunity to apply information and material into their own lives. In Type 3, the emphasis is on establishing problem solving procedures while this type focuses on application of those procedures across new boundaries.

Course Design

The structure of the course Engineering Construction had several distinctive components each designed to offer a learning style to succeed. For example, MapleTA was useful to the Type 3 learners, while the project created opportunities for types 1 and 4 to shine. The layout of the course is shown is shown in Table 1.

Table 1: Course Structure

WEEK	TOPIC	READING	MAPLE TA	JOURNAL	PROJECT	SKETCHING
21+22/7	Equipment Costing	Chapter 2	Time Value of Money			
28+29/7	Equipment Costing	Chapter 2	Hourly Cost			
4+5/8	Power and Safety	Chapter 3	Power-Transmission			
11+12/8	Power and Safety	Chapter 3				Sketch 1 Due (for Feedback)
18+19/8	Backhoe Excavators	Chapter 4	Backhoe Production	Submission 1		
25+26/8		Chapter 4	Standard Times			Sketch 1 Uploaded
1+2/9	Cranes	Chapter 7	Crane Capacity			Sketch 2 Due
Semester Recess (Mon 3 –Fri 10 Sept.)						
15+16/9	Mid-term exam Deep Foundations	Chapter 9			Phase 1	Sketch 2 Uploaded
22+23/9	Deep Foundations	Chapter 9				Sketch 3 Due
29+30/9	Temp Structures	Chapter 10		Submission 2		Sketch 3 Uploaded
6+7/10	Bridge Construction	Chapter 11			Phase 2	
13+14/10	Reminders, Bridges, Oral Present, Prep Final Exam, Exec Summary Writing	Chapter 11				
18+20/10	Project Presentations					
4/11	Final Exam					

Over the duration of this course, students were given assignments consisting of:

- Six computerized MapleTA assignments (first half of the semester)
- Engineering sketches (3 compulsory), 2 voluntary (bonus marks)
- Optional journal writing (two submissions for feedback only, peer-review)
- Mid Term and Final Exam (Mid-term was optional instead of journal))
- Group Project with written report and oral presentations
- 24 Polleverywhere quizzes

As indicated, writing a class journal was optional replacing the mid-term exam. All but 19 students selected to write the journal although they acknowledged that it would be hard for them. Right after the students received comments from their 16 tutors, a voluntary journal writing seminar was held. Each weekly journal entry had required the students to address three distinctive questions: 1) 'What happened this week?', 2) 'What is the most interesting thing you have learned this week and why?' and 3) subject specific question.

The due date of the sketches was spread out as the demand increased. Tutors were trained to assess the quality of the sketches submitted during the tutorials allowing them to give immediate feedback. Sketches that did not pass the established criteria of minimal quality were returned with an encouragement to improve and upload in jpg format to the common data base. The topics of the three sketches were:

- Large off-highway truck in orthogonal views (Scale to fit it all on one page and details required? Why are these engineering details important?)
- Trenching backhoe damaging a gas pipe causing an explosion. (How did it happen?)
- Lift plan for cranes to disassemble a steel tower (What is needed to make this operation safe considering laws of physics?)

Discussion of Results

From the analysis of Kolb's learning preference questionnaire, we found that students in this course were mostly Type 3 dominant, that is to say that they are more of the 'doers' and enjoy processing information through application. They prefer to toss the manual aside and embrace the computer program by themselves as discussed earlier. The second most dominant learning preference overall is Type 2 which refer to those who prefer a learning style that emphasises to a certain extent on 'spoon-feeding' where information transfer from lecturer to students is still a vital part of learning. Interestingly though, we also found that students whose English is their second or third language were mostly Type 2 dominant which could possibly suggest that the learning style of these international students (mostly from Asian countries such as China, Hong Kong and Korea) are attributed to the learning culture and system in the Asian region. Figure 3 compares between overall as well as learner types of US and Korean students. This further suggests that cultural differences may have an impact on preferred learning styles. More in -depth studies are required to further validate this observation.

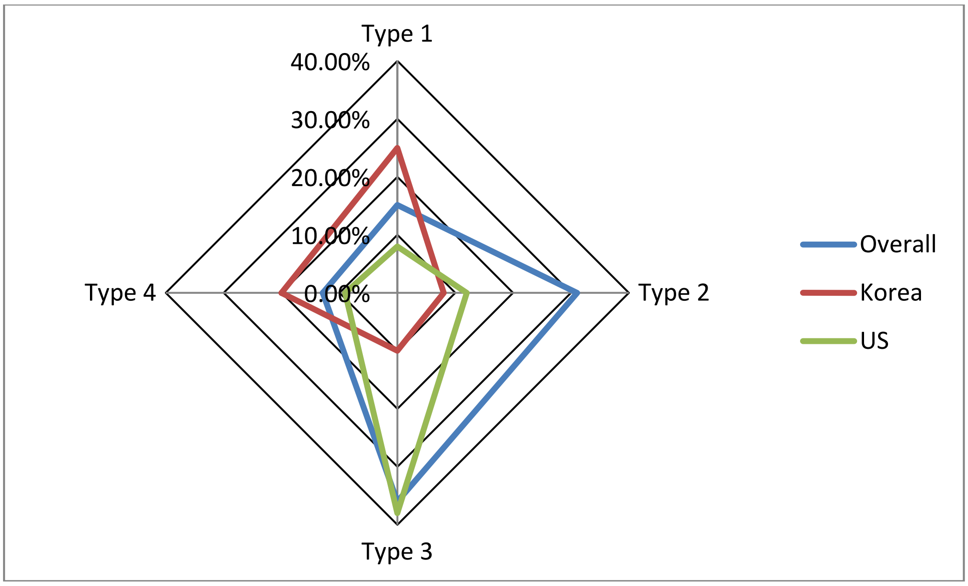


Figure 3: Learning Style Preference of Students

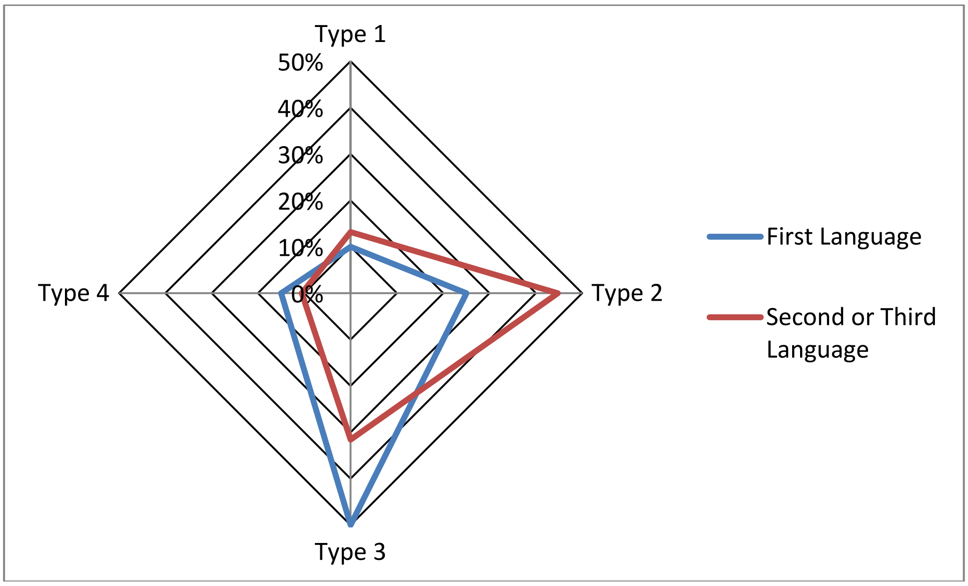


Figure 4: English Language and Learning Preference

Differences According to Learning Types

As mentioned earlier, the first sketch consisted of practicing orthogonal views of a large dump-truck. . As expected, the quality of this first exercise varied drastically. The tutors were expecting drawings that went beyond simple contours but sketches that conveyed an understanding of its most essential components and functions. The question was: How can one assert looking at the sketched vehicle that it is an off-highway vehicle able to safely transport large amounts of rock material up a steep incline? Again, those who did not meet some basic expectations were allowed to redo the first attempt without any penalty.

This first sketching assignment showed that, in general, Type 1 learners demonstrate a deeper appreciation of construction equipment, albeit one as simple as a truck. From the representative example shown in Figure 5, we can see that the student paid close attention to several key details. Firstly, the threads of the tyres, their equal size and round shape as well as the bolts that attach the wheels to the axles. The steps, safety railings on the upper level and the rear-view mirror are neatly drawn as well as the drive shaft that runs into the differential transmission box. This comes as no surprise as Type 1 learners are generally perceived as those who are inquisitive and constantly looking to answer the question 'Why'? Such inquisitiveness may have prompted this group of students to really look out for engineering details in the truck.

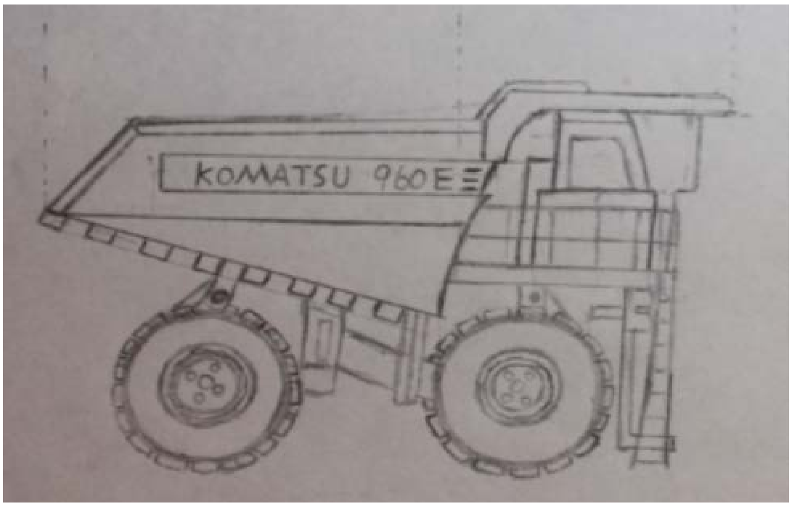
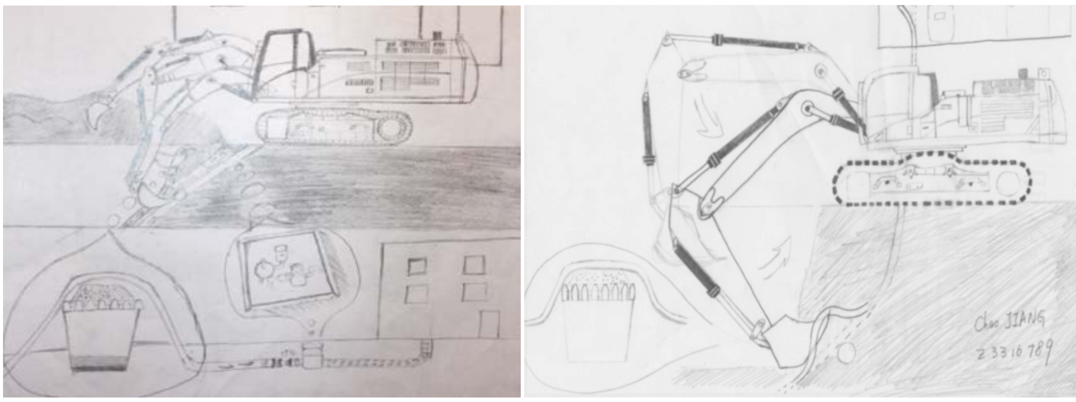
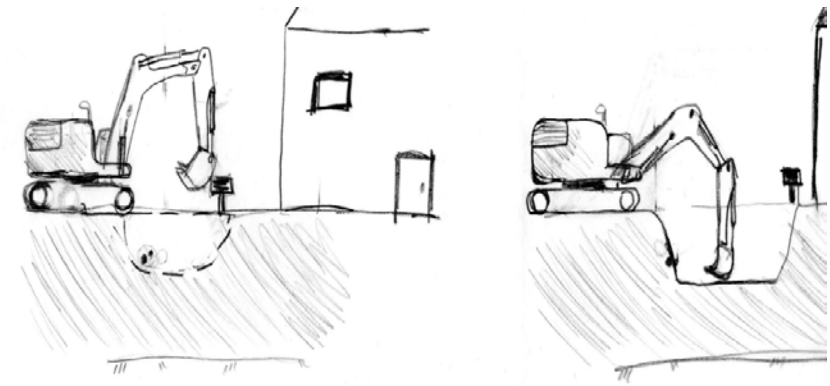


Figure 5: Side view example from a Type 1 learner

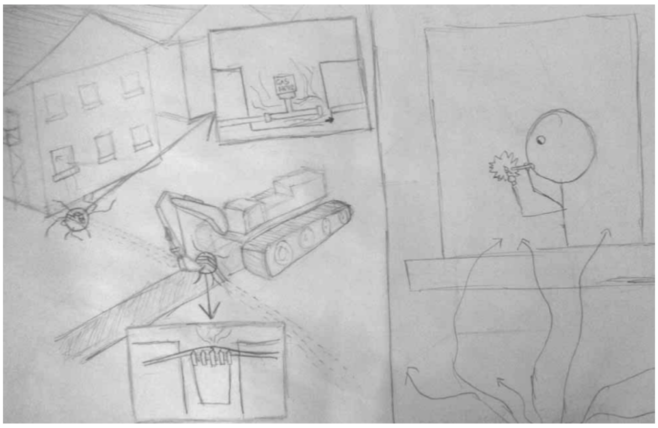
For the second assignment, students were required to express the result of a forensic investigation of a gas explosion caused by a trenching backhoe damaging a buried gas line supplying gas to a single family house. The task was to turn a written report into a visual story of how it happened from an engineering perspective. Thus, the actual explosion was irrelevant. This assignment yielded very interesting sketches. For example, we found that those who indicated a preference for Type 1 learning were once again very meticulous in the level of detail given to the excavator and the pipeline underneath the ground. Type 2 learners showed an understanding on 'how' the excavator operates judging from the arrow sign which signals the movement of the arm. Interestingly, type 3 learners have a tendency to stress on 'what' is happening and demonstrate an understanding of the after effect of the excavation work for example the creation of a deeper trench. Creatively, type 4 learners were able to demonstrate the 'what -if' learning style. One of them highlighted a scenario of a man smoking while the gas leaks from the pipe into his house as depicted in Figure 6 d).



a) Student with Learning Type 1 b) Student with Learning Type 2



c) Student with Learning Type 3



d) Student with Learning Type 4

Figure 6: Comparison of Forensic Sketch

These observations may indeed indicate that students belonging to the different learner types may have an impact on what they focus their attentions on when conveying their understanding. Future sketching assignments could be designed to allow each group to exult on their strengths while being encouraged to address the other areas as well.

Comparative Assessment of Understanding

The second part of the study involved a comparative analysis of how students expressed their understanding of the class material in written journals and engineering sketches. This was possible since almost all the students chose to write the class journal instead of doing a mid-term exam. Of course, the journal for the week of September 18 focused on what was learned about backhoe excavators while sketch No. 2, due two weeks later, focused on the backhoe accident shown in Figure 6. The following present samples taken directly from the original journals emphasizing what was the most important learning experience for that week:

Student with Learning Type 1:

> 'Excavating with a backhoe has the potential risk of hitting an underground utility which could cause serious accident happen. So it is necessary to mark the area where cables or pipes are buried. Different colors are used to represent different utilities'

Student with Learning Type 2:

> 'Firstly, operating the boom cylinders to lower the boom parts and let bucket dig in soil. Then, moving the stick cylinder to cut soil and keep the bucket cutting soil horizontally by adjusting boom cylinders. Too larger or small angle will reduce the efficiency and increase the money cost, which is why we put an operator factor in fuel cost calculation since the elevation angle is controlled by operators. In the end, lifting the boom and making bucket open towards up for containing goods.'

Student with Learning Type 3:

> **'**There are four main steps of backhoe to digging a hole, first align to cut angle then penetrate, the third one is cut and the final step is extract-lift. However, it seems hard to know how much energy we need to accomplish all the process due the variables in machine or soil.'

Student with Learning Type 4:

> **"**For digging the path, the engine should be power to lift up the cylinders and arms, and then control the bucket to dig in the soil. The action starts with lifting the excavator arm and the bucket enter in dense soil in a desiring point and angle. Then the bucket contract for a distance to cut the soil. During the cut action, the bucket is suffering the friction force from each of the side of bucket, such as the soil reaction force, friction force from the bucket inside and outside"

It is interesting to notice that the type 1 learner focuses his or her attention on "why" the accident happened rather than on the mechanical aspects of a digging motion. Furthermore, type 4 found the effects of the different friction phenomenon most interesting while the "what" learner was very particular in explaining the "exact" steps needed to move the boom. Besides the problematic status of the use of the English language, these samples do demonstrate the difficulties students have in expressing concisely the many issues related to the simple digging motion of a backhoe excavator. The reader may be aware of some of the key concepts: a) engineering mechanics-trigonometry, b) friction and cutting forces, c) power distribution, d) soil mechanics, e) production cycles, f) energy/fuel consumption and cost, g) danger of buried utilities, h) safe operation and i) operator control.

Strategies for Assessing Deep Understanding

The comparative analysis of journals and sketches provides evidence that, as expected, the different learning types seem to focus their attention on different aspects of what is being studied. We also noticed that writing creates difficulties in presenting complex operations especially when compared to sketching. Is there a way that we can develop a scale that shows how much a student understands the material when expressed in a drawing or in writing? The basis for such a scale could be Bloom's Taxonomy of thinking, a model presented in Figure 1.

While the journaling exercise allows us to access both engineering knowledge and comprehension at the most basic level of hierarchy (i.e. understanding) , it is still sketching that provides an avenue to assess engineering understanding at much higher levels in the pyramid arguably at both the application and analysis level. For example, looking at the extracts taken from the students' journal a large majority of the descriptions of the backhoe operations are very poorly written and often convey a completely different message from what is intended some going as far as to claim that 'buckets contract'. Descriptions are also often scanty for example, 'first align to cut angle then penetrate, the third one is cut and the final step is extract-lift' and does not provide much depth as to the level of understanding in terms of engineering mechanics. At best, evidence from the journaling exercise shows that students are able to only convey and express ideas at the two lowest levels of Bloom's hierarchy, remembering and understanding. For example, referring to the extract from learner type 1, the student was able to identify the risk involved with using a backhoe and describe the need for using different colours to represent different utilities. Extracts from types 2,3 and 4 are also reflective of a description on the manner in which a backhoe operates and not so much at an analytical level where a student is expected to analyse and determine relationships among different component parts.

Sketching on the other hand allows better identification of connections and relationships such as how construction equipment such as the backhoe or crane functions, the different components involved, arrangement and logic as evidenced from this course. Generally, what was found is that the sketches produced by these students were able to convey a much deeper understanding of their engineering knowledge where use of words has failed. In particular, we were able to better assess their understanding of the movement of the boom and bucket, the connections between the body and the boom and also how well students are able to visualise potential problems occurring (i.e. gas leakage as a result of backhoe operation). The sketching exercises also provide us with an indication of the student's comprehension of the use of scales and dimensions (i.e. how long should the boom be compared to the body) which is extremely crucial in engineering communication but difficult to convey with words alone.

Correlation Analysis

Using the Statistical Package for Social Sciences (SPSS), a correlation analysis was carried out to identify if there is a connection between preferred learner types and journal marks.

The general formula proposed for investigation is expressed as follows:

$$\text{JournalMarks} = \beta_0 + \beta_1\text{FirstQuad} + \beta_2\text{SecQuad} + \beta_3\text{ThirdQuad} + \beta_4\text{FourthQuad} \quad (1)$$

Type 1 Preference

The results of the analysis are presented in Table 2 and it was found that there is a positive correlation between first quadrant scores and journal marks for those with a Type 1 Learning Preference. Additionally, this conclusion is significant at p-value < 0.05. Meanwhile, this appears to be vice versa for both the second and fourth quadrant scores with journal marks.

Table 2a: Model Summary

Model	R	R Square	Adjusted R Square
1	.629	.395	.234

Table 2b: Correlation Analysis for Type 1 Preference

		Journal	Firstquad	Secquad	Thirdquad	Fourthquad
Pearson Correlation	Journal	1.000	.441	-.107	.195	-.359
	Firstquad	.441	1.000	.243	.306	.058
	Secquad	-.107	.243	1.000	.629	.107
	Thirdquad	.195	.306	.629	1.000	-.169
	Fourthquad	-.359	.058	.107	-.169	1.000
Sig. (1-tailed)	Journal	.	.026	.326	.204	.060
	Firstquad	.026	.	.151	.095	.404
	Secquad	.326	.151	.	.001	.326
	Thirdquad	.204	.095	.001	.	.237
	Fourthquad	.060	.404	.326	.237	.

Type 2 Preference

From the results depicted in table 3, it can be observed that even though there appears to be a positive correlation between first and second quadrant scores and journal marks, however this correlation appears to be very weak. In addition, the results are not statistically significant as p-value >0.05.

Table 3a: Model Summary

Model	R	R Square	Adjusted R Square
2	.262	.069	-0.052

Table 3b: Correlation Analysis for Type 2 Preference

		Journal	Firstquad	Secquad	Thirdquad	Fourthquad
Pearson Correlation	Journal	1.000	.089	.127	-.068	-.142
	Firstquad	.089	1.000	-.535	-.462	-.456
	Secquad	.127	-.535	1.000	.513	-.309
	Thirdquad	-.068	-.462	.513	1.000	-.423
	Fourthquad	-.142	-.456	-.309	-.423	1.000
Sig. (1-tailed)	Journal	.	.303	.231	.346	.204
	Firstquad	.303	.	.000	.002	.003
	Secquad	.231	.000	.	.001	.033
	Thirdquad	.346	.002	.001	.	.005
	Fourthquad	.204	.003	.033	.005	.

Type 3 Preference

Table 4 indicates the results of the correlation analysis for those with a preference for type 3 learning styles. It appears that for this group of students, there is a statistically significant negative association between their first quadrant scores with journal marks (r=- 0.363, p-value <0.05). On the other hand, there is weak correlation between second quadrant scores and journal marks.

Table 4a: Model Summary

Model	R	R Square	Adjusted R Square
3	.420	0.176	0.108

Table 4b: Correlation Analysis for Type 3 Preference

		Journal	Firstquad	Secquad	Thirdquad	Fourthquad
Pearson Correlation	Journal	1.000	-.363	.091	.232	-.142
	Firstquad	-.363	1.000	-.168	-.189	-.029
	Secquad	.091	-.168	1.000	.331	-.283
	Thirdquad	.232	-.189	.331	1.000	-.219
	Fourthquad	-.142	-.029	-.283	-.219	1.000
Sig. (1-tailed)	Journal	.	.004	.257	.047	.155
	Firstquad	.004	.	.115	.088	.419
	Secquad	.257	.115	.	.008	.020
	Thirdquad	.047	.088	.008	.	.058
	Fourthquad	.155	.419	.020	.058	.

Type 4 Preference

Similarly, there is no positive correlation between first quadrant scores and journal marks for those who have indicated a preference for type 4 learning style. Results are as shown in Table 5.

Table 5a: Model Summary

Model	R	R Square	Adjusted R Square
4	0.268	0.072	-0.142

Table 5b: Correlation Analysis for Type 4 Preference

		Journal	Firstquad	Secquad	Thirdquad	Fourthquad
Pearson Correlation	Journal	1.000	-.106	.231	.081	-.155
	Firstquad	-.106	1.000	-.643	-.552	-.167
	Secquad	.231	-.643	1.000	.091	-.088
	Thirdquad	.081	-.552	.091	1.000	-.543
	Fourthquad	-.155	-.167	-.088	-.543	1.000
Sig. (1-tailed)	Journal	.	.342	.186	.379	.276
	Firstquad	.342	.	.003	.011	.260
	Secquad	.186	.003	.	.365	.368
	Thirdquad	.379	.011	.365	.	.012
	Fourthquad	.276	.260	.368	.012	.

As well, the correlation between sketches -journal marks and sketches -exam marks for this course were explored. The summary of the results are presented in Tables 6 and 7. Based on the analysis, it appears that there is a lack of correlation between the quality of sketching -journal marks (ρ =0.101, p-value >0.1) and sketching –exam marks (ρ =0.3, p-value<0.05). Only the analysis for sketching-exam marks is found to be statistically significant. However, care must be taken in interpreting these results as there is a certain degree of subjectivity associated with the marking of the journals and sketches.

Table 6: Correlation Analysis between Sketching and Journal Marks

Descriptive Statistics

	Mean	Std. Deviation	N
Sketches	81.4968	16.52942	126
Journal	92.0952	11.82433	126

Correlations

		Sketches	Journal
Pearson Correlation	Sketches	1.000	.101
	Journal	.101	1.000
Sig. (1-tailed)	Sketches		.130
	Journal	.130	
N	Sketches	126	126
	Journal	126	126

Table 7: Correlation Analysis between Sketching and Student's Exam Marks

Descriptive Statistics

	Mean	Std. Deviation	N
Sketches	81.4968	16.52942	126
Exam	76.0587	7.95209	126

Correlations

		Sketches	Exam
Pearson Correlation	Sketches	1.000	.300
	Exam	.300	1.000
Sig. (1-tailed)	Sketches		.000
	Exam	.000	
N	Sketches	126	126
	Exam	126	126

Relevance to Engineering Education

The results suggest that there is a lot of potential for using sketching as a tool to enhance deeper understanding of construction equipment and processes as evidenced from this study. Academic practitioners should note that there appears to be a tendency for the influence of different learner types and the messages they wish to convey through their sketching assignments, therefore assessments involving sketching would only be effective if they were explicit in nature, particularly in terms of the expected outcomes. This study also demonstrates the use of journaling as a tool for communication and although appears not to be as effective in terms of assessing deeper understanding in construction it still has a major role to play. Future research should definitely consider examining the possible synergies between journaling and sketching to enhance better understanding.

Conclusion

Overall, the findings of this study demonstrate that there are differences in preferred learning styles which could be influenced by cultural backgrounds of students. The use of journals alone may not be adequate to holistically measure understanding. This paper argues for the use of sketching in engineering teaching as it allows for better identification of connections and relationships between construction equipments as well as allows assessment of students' understanding at a higher level based on Bloom's taxonomy. Based on the correlation analysis, it was also interesting to observe that only those dominant in Type 1 learning styles had higher marks in journal writing, this opens up a whole new argument as to how sketching assignments can be incorporated in the engineering curriculum to ensure that every student has an equal opportunity to demonstrate their understanding of engineering.

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