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ABSTRACT

A concern in engineering education is students adopting a 'recognise and reproduce' approach to problem solving. In this study, an assignment was conceived and analysed through Legitimation Code Theory – which allows for visualisation of students' thinking, and to illuminate how students construct knowledge in open-ended problem solving. The assignment was based on students posing their own exam-style questions. Evidence for its subjective effect on the students was generated through students' responses to a questionnaire. Most (72%) students found the assignment assisted their understanding and context of the work, while 75% believed the open-ended nature of the assignment would make them better engineers. About 52% said they would change the way they study based on the insights and self-reflection from the assignment. While several students discuss an approach focussed on repetition, recognition, and algorithmic learning, the assignment showed students using an open-ended approach.

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Introduction

A recurring and substantial issue during undergraduate engineering education is students' adopting a superficial learning route to problem solving through 'pattern recognition', which can sometimes belie a poor grasp of the content and concepts being examined (Felder et al. 2000). Further, students take their learning cue from the assessments used by lecturers – focusing energy on those areas which will be examined (Hattingh, Dison, and Woollacott 2019). In a field such as engineering, 'applied knowledge grows through an accretion of practical solutions to particular problems' (Muller 2009). It is important to position 'problem solving' as a fundamental *raison d'etre* for engineering – an important aspect of engineering is the utilisation of knowledge through conceptual grasp and application to other situations (Wolff, 2015).

This concern of superficial learning, where application to different contexts is difficult through students being mired in the specific (Hattingh, Dison, and Woollacott 2019), can be particularly pronounced in courses such as reactor design, which implements an algorithmic methodology to problem solving. Students can easily hide behind recognising the pattern of the algorithm, rather than grappling with (and therefore experiencing 'cumulative learning' (Maton 2009)) the meaning and fundamentals behind the said methodology. These superficial learning methods can give rise to 'correct answers' but shallow understanding, or, as is often the case, the work is done only because it is an assignment and the course cannot be passed unless it is completed, without arousing the students' interest (Kember and Danping 2016). However, the educator might be cautious of considering such approaches to learning only in terms of 'deep' vs 'surface' learning – there is

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complexity here potentially not captured by such binary classification (Case and Marshall 2004; Tormey 2014; Kember and Danping 2016). Techniques that allow educators to 'peer behind the veil' to understand routes to student learning and skill development are needed.

On the basis that assessment style can drive the type of engagement students make (Hattingh, Dison, and Woollacott 2019), one assessment method which has seen application in courses susceptible to 'pattern recognition' is student problem-posing (usually in the guise of multiple-choice question creation) (Kaberman and Dori 2009; Jobs et al. 2013; Nwosu et al. 2013; Shakurnia, Aslami, and Bijanzadeh 2018; Walsh et al. 2018). In this methodology, students are asked not only to answer questions posed to them, but rather to devise questions (and solutions) of their own, within particular subject parameters. As will be discussed later in the article, the use of question-posing elicits a more open-ended response from students, broadening the focus from an algorithmic approach to a situational one. Indeed, the benefit of students posing questions is the subject of ongoing research (Walsh et al. 2018), and has been found to be particularly helpful in a school classroom context (Dori and Herscovitz 1999; Chin, Brown, and Bruce 2002; Kaberman and Dori 2009). However, in large and generally unresponsive university classes, eliciting verbal questions from students can be challenging, time consuming, or prone to eliciting questions from only the more vocal of students, to the detriment of the remainder.

The potential of written question-posing in the reactor design context is in allowing (and forcing) students to explore the algorithmic nature of reactor design from multiple perspectives, and in so doing enabling students to utilise more open-ended approaches. That is, they need to (i) conceive of the problem from their own experience, (ii) simultaneously and iteratively set-up the question and solution, and (iii) consider both the correctness and completeness of the mathematics, and not simply as a way to 'game the system', but also whether the question examines the content appropriately.

This study aims to demonstrate a teaching intervention using written student-led question-posing which improved student involvement, understanding and self-reflection.

Context

This study was conducted within the third year of a four-year chemical engineering degree programme at Stellenbosch University, South Africa. The programme is IEA-aligned and accredited by the Engineering Council of South Africa, a signatory of the Washington accord. As such, while there are context and societally specific aspects within this programme, research conducted with these cohorts is likely to be broadly applicable to other global institutions and engineering programmes.

The department in which this study is situated runs or is involved in a number of educational initiatives, facilitated by lecturers who are active contributors to the educational literature. A common sociological tool (in Legitimation Code Theory, which will be outlined below) is shared as a language of analysis by these researchers. Multiple projects, such as Engineering Education Existing Staff Capacity Enhancement Programme (EEESCEP) and University Capacity Development Grant (UCDG) support lecturers. As a result, an emerging body of theorised and empirical engineering education work has being produced in the department; redesigning curricula, implementing initiatives, and attempting to improve student development. One potential point to consider when examining the data generated from this study is that it is likely that this cohort of students would have taken part in other educational initiatives in earlier courses. These initiatives may or may not have confounding or amplifying effects on the results seen here, although it is not possible to disaggregate these potential effects since no control group is possible.

The course in which we ran this practical instructs students on the methods and tools used in reactor design. This includes solution methods around two key reactor types: plug flow and continuously stirred tank reactors, including time residence distributions, and substrate product conversions using simple kinetics. The conceptual level of this course falls within third-year university degree level, with insightful students moving into Honours or 4th-year university level thinking. The course forms one of the core chemical engineering knowledge streams within the degree, and students who struggle with this work have tended to perform poorly in later subjects.

Theoretical framework

Engineering education must walk a tightrope between examining 'calculation ability', and fundamental understanding – creating assessments which parse these can be challenging (Olds, Moskal, and Miller 2005). In order to appropriately design and analyse pedagogies, interventions, and teaching methodologies, a theoretical framework to conceptualise student learning is needed. One framework for understanding learning that has gained increasing prominence in the field of the sociology of education is Legitimation Code Theory (LCT) (Maton 2014; Maton, Hood, and Shay 2016). LCT is a tool for exploring practices in terms of their organising principles, and is gaining traction in the educational space, since it allows shifts or positioning in cognition to be plotted on a series of Cartesian planes, of which there are several lenses to choose from, depending on what analysis is desired. In this article, the Epistemic Plane will be used: this dimension examines the interplay between knowledge and knower, and in particular one can focus on knowledge practices – particularly apt for a discussion on knowledge generation in a 'knowledge-centred' practice such as engineering. The plotting of the interplay of meaning-making moments allows for visualisation of the invisible internal experience of the student.

The Epistemic Plane allows for a graphical description of how students experience the relationship between engineering concepts and approaches to solving these and may allow insights into how to improve depth of learning. Figure 1 illustrates the Epistemic Plane: the abscissa defines

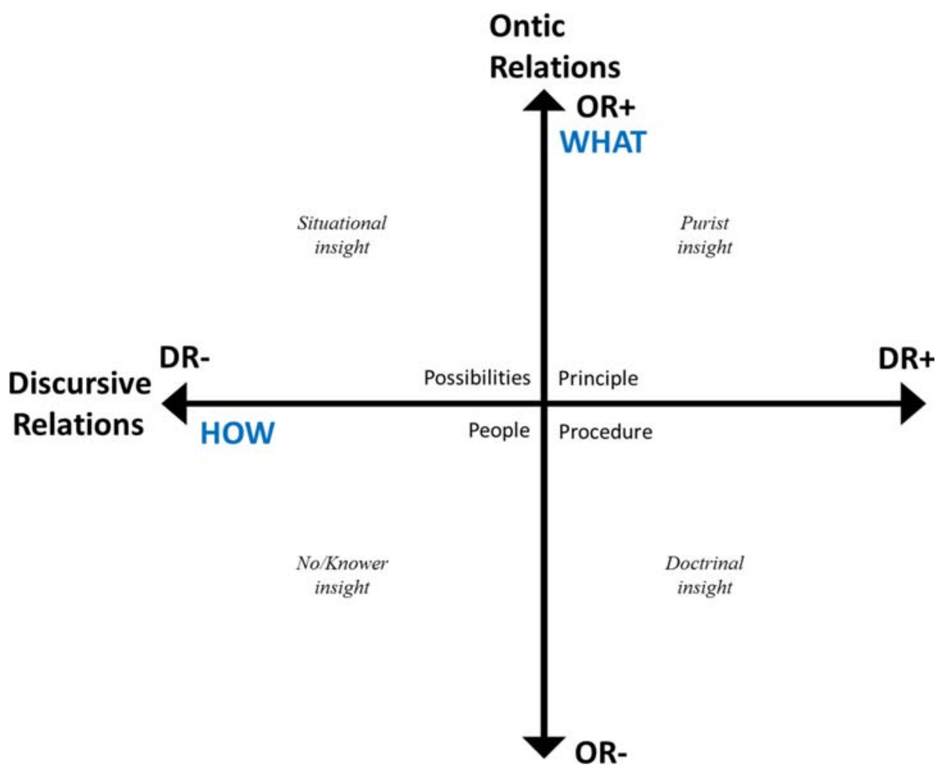

Figure 1. The Epistemic Plane, describing discursive relations (left to right: weak to strong), and ontic relations (bottom to top: weak to strong) (modified from Maton (2014))

the 'Ontic Relations' or what can be considered (in an engineering context) as 'What' – as in, what concept or scientific entity is being discussed. The higher up the abscissa, the higher the comparative 'strength' of the concept, or potentially how well defined the problem is. The ordinate defines 'Epistemic Relations', or 'How' a problem's solution is defined. If there is a single accepted methodology then the 'How' is high, whereas an open-ended or problem with multiple potential approaches would be further to the left.

A useful way to use this plane is through considering characteristics of the generalised 'quadrants', which can be seen in Figure 1: That is, concepts or approaches that sit in strongly bounded discursive relations (e.g. well-defined problems), with a strong ontology (i.e. their description is accepted and fully defined) are referred to as being in the 'purist quadrant' or the quadrant where the 'principle' is most important. Likewise, within the 'doctrinal' or 'procedures' quadrant, the methodology is well defined (to the right of How) but the type of problem may be more variable or ill-defined (bottom of What) eg applying a single method to various problems of similar mathematical shape. The 'situational' or 'possibilities' quadrant could define open-ended problems – those that are well defined (high What) such as 'design a way to make aspirin' but with multiple possible approaches to the solution (low How). The 'no/knower' or 'people' quadrant considers those aspects which are not necessarily well defined in terms of a problem, or where the problem-solvers themselves are important. Aspects such as teamwork might fall within this quadrant.

Summarised:

- Purist insight is required where a phenomenon has strong ontic relations (a universally accepted identity) and strong discursive relations (a standardised approach). For example, using Newton's law to solve gravitational attraction.
- Doctrinal insight describes practices where the approach or procedure takes precedence, such as the rules of the scientific method, differentiation in Calculus, or perhaps an algorithmic solution methodology. For example, using the square distance law to solve gravity or magnetic attraction.
- Situational insight denotes practices dictated by phenomena with strong ontic relations (i.e. the problem is understood or described), but where the discursive relations are weaker (there are more possibilities and open-ended approaches). For example, being asked to figure out how to calculate a rocket's trajectory, one component of which would be to use Newton's law, but which would entail other approaches too.
- No/Knower insight is evident when a practice is either 'anything goes' or not determined by knowledge, but rather the intrinsic characteristics of the knowers (or social relations). For example, understanding the socio-political impacts of launching a rocket. Or working as a team.

The use of this tool allows the researcher to attempt to plot and visualise the approach and experience of the student, through usual class activities, as well as through interventions such as the one discussed in this article. The tool illuminates conceptual shifts and positioning, and so may give insight into the learning trajectory or destination of students. If a theory of 'cumulative learning' (Maton 2014) can be investigated, illustrated, developed and measured, then perhaps similar interventions might be plotted and implemented in other contexts, to the benefit of our students.

Methodology

In order to address the project aim of investigating a student-led question-posing approach to reactor design, using the theoretical framework of LCT to understand student conceptualisation, the following approach was adopted: Students ($n = 72$) were given an assignment (which is included in the supplementary material for reference), part of which was to develop an exam question on the work covered in the course. The question needed to include a model solution, and a mark break down, as well as an analysis using Bloom's Taxonomy (Bloom 1956) – the figure given to the students is reproduced herein Figure 2. The students were given several weeks to complete this assignment, with the hand-in date towards the end of term. After completing and handing in the assignment, the students were requested to fill in an exit questionnaire where perceptions were evaluated, and where students were asked to comment on their experiences of the exercise and how it impacted their understanding of the theory taught during lectures (61 responded). The students took the request to self-evaluate seriously (as could be expected with senior engineering students), since 84% took the trouble to fill in the voluntary questionnaire. Further, the responses were not superficial, in the main: there was much insight, questioning, and maturity in their responses. Thus the data are limited but useful.

Response to the questionnaires was voluntary, whilst attempting the assignment was compulsory. Questionnaires were not completed as anonymous responses, thereby enabling the monitoring of the performance of individual students within the module; however, only the contributing authors had access to data linked to individuals. Ethical clearance for this project was granted through the international, collaborative Existing Engineering Educator Staff Capacity Enhancement Project (EEESCEP) (FREC:REF:025/18). Data were collected strictly according to university ethics protocols, after consent to use the data for research was obtained from participants. Data were anonymised for inclusion in this article.

Assignment

The assignment was designed to encourage students to consider carefully the tools and methodologies they had learned in the course and put these in practice in setting up an appropriate exam question for 25 marks. The students were given a brief lecture on Bloom's Taxonomy, and instructed that the exam question should conform to a suitable level of conceptual grasp for a third-year subject. A full solution, including mark scheme, was to be included, with insight from a Bloom's analysis indicating their understanding of the level of complexity of each portion of the exam question. The assignment is given in Appendix A.

Exit questionnaire

The exit questionnaire consisted of seven questions, the first of which asked students to evaluate the amount of time spent on the assignment, three aimed to probe how the students experienced the assignment – its impact on their understanding, their standing as engineers, and their study

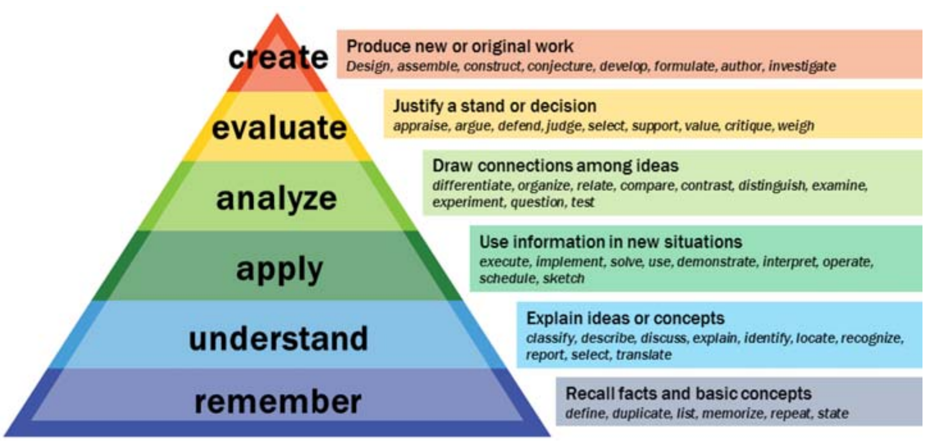

Figure 2. Bloom's taxonomy, reproduced under creative commons from Vanderbilt University Center for Teaching (Armstrong 2018).

methods. One asked them to reflect and comment on Bloom's level of the assignment, and the final two asked for more general feedback from the assignment – if they had the option, what assignment would they give, and a request for further comments. The questions required a written response from participants, giving them the opportunity to give voice to their experiences. While we must take self-reported data (such as the students' report of how many hours they spent) with a pinch of salt, the responses nonetheless give an indication of student engagement with the assignment. The complete set of questions and wording is provided in Appendix B. The responses were collected, pertinent quotations were taken, anonymised and collated.

Analysis using legitimation code theory

Using the data generated as described in the sections above, the student responses were used to plot motion across the Epistemic Plane through analysis using a 'translation device' (Maton, Hood, and Shay 2016). This device explicitly outlays how data is converted from (in this case) student discussion to positioning on the Epistemic Plane (Figure 1). In this study, the following translation device was employed (Table 1):

Consideration of how the assignment was designed, how the students experienced the assignment and their meaning-making progression was critically reflected on post-analysis.

Results and discussion

In the main, the assignment can be considered a success. Students, for the most part, found the experience positive and felt that it contributed to their understanding of the module content. Many experienced insights into their learning prompted by the assignment. From the lecturer's perspective, while marking these assignments is time consuming (since each is different), they had the unintended consequence of providing a number of questions suitable for use in future examinations.

Approaches to learning in reactor design

Using the questionnaire data, and comments received during the online course feedback (anonymised to numbers), we can examine how the students perceived the effect of the assignment, particularly in contrast to their usual or current learning strategies. From a constructivist paradigm, students are generating their own knowledge through experimentation, tool usage, and conflict (Powell and Kalina 2009; Vygotsky 2012) – as such, the insights they give on their own account can allow us to peer behind the veil and see how they are learning, even when they themselves might not realise. For instance, the following demonstrates the concern voiced in the introduction – that much learning (particularly in reactor design) is algorithmic, and superficial:

> Student 1: 'I would rather focus on practicing … than on trying to understand the theory … '

And the perennial student concern that with limited time available for study, a trade-off between solid understanding and sufficient ability to calculate is often needed:

> Student 2: 'with limited time some parts of the work I memorise without understanding completely'

Table 1. Translation device employed in analysing student questionnaire data.

	DR+	*DR-*	*OR+*	*OR-*
Indicator	Well defined methodology employed. Techniques and tools explicit.	Multiple methodologies possible. Techniques or tools implicit, unknown or unrealised.	Significance of principles realised, and application to multiple systems discussed	Little reference to underlying principles. Replicate and repeat. Independent of context.

Some, however, voice a different opinion: that they can get caught up in 'theory' (implying an attempt to grapple with the underlying principles), when they should perhaps spend more time on a mechanistic practicing of problems:

Student 3: 'I would normally spend too much time on theory … working through examples would be of more use'

Using the lens of LCT's epistemic plane, we can plot these opinions. This can give us a representation of how students commonly approach this course. Doing this in Figure 3 illustrates the key concern – that many students draw down theory into a 'rinse and repeat' procedural methodology. They expect to copy methods from previous examples through recognition and repetition.

Indeed, students often request further problems of the same sort with which to practice:

Student 4: 'doing mass amounts of problems … is more time efficient than spending 6 h on a single problem'

Further implying a reliance on a methodology where students recognise and can repeat solution methodologies via multiple exercises of the same type:

Student 5: ' … unlike the other exercises which are required to do one thing again and again … '

In itself this request for further examples and exercises is not necessarily cause for concern – indeed, as Case and Marshall (2004) point out, there is a strong case for an algorithmic approach to learning, on the assumption that the learning does not end there; a point further expounded on by Kember and Danping (2016), in relation to how students who do adopt an algorithmic approach can move

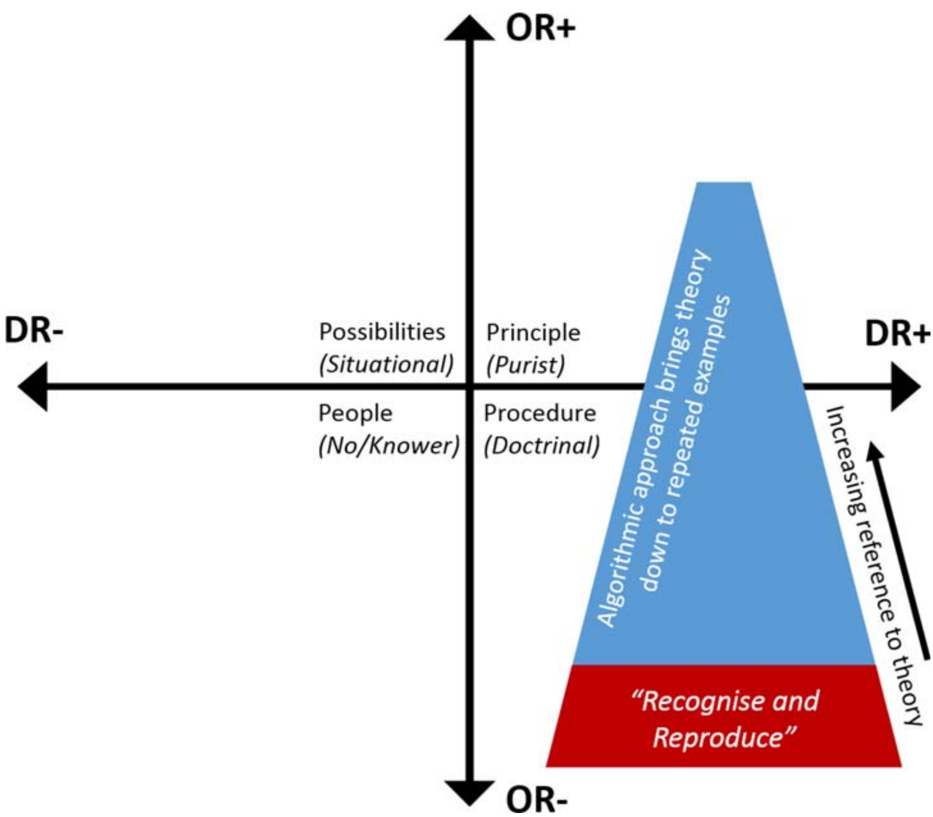

Figure 3. Epistemic plane detailing ontic and discursive movement within reactor design. Modified from (Pott and Wolff 2019)

beyond that to deeper understanding, through first formulating a strong skill foundation from which to build. The students often recognise this approach to subject mastery:

Student 6: 'you learn the theory through practicing examples'

Developing the tools and methodologies to solve reactor design problems can be achieved through this repetition-based approach, but it can also develop students who can perform the calculations, but have no fundamental understanding of how those solutions came to be, or how they represent real-world phenomena. There is a balance or extension which is needed between simply being able to perform the calculations (which can be gained through algorithmic learning) and a deeper, more widely applicable understanding of the underlying concepts.

Using LCT, we can locate this 'recognise and reproduce' as having weak ontic relations – where the exact contextualisation or positionality of the problem are sometimes less important (although context, and underlying derivation do give some information on what *tool* will be used). Discursively, we can say that these types of calculation methodologies are 'well-defined': the students recognise the shape of the mathematics, they recognise the specifics of which equation to choose for which situation: and therefore have stronger discursive relations. This then situates this approach quite strongly within the *procedure* quadrant, with a spectrum on both Ontic and Discursive relations. The students apply a *procedure* to solve the problem, without necessarily deeply understanding why such a procedure works.

Assignment intention, application, and implications

In reference to the assignment, the students who responded to the questionnaire were mostly positive that it improved their understanding. Some 72% answered question 2 (Did this assignment improve your understanding of 'reactor design'?) positively, and several elaborated on what aspects they found to be useful.

In contrast to Figure 5, if one plots the *intention* of the assignment (Figure 4), it would sit very much in the situational quadrant – that is, the problem is well described (design a *reactor design* question) giving it strong ontic relations, however, there are numerous methods, concepts, implications, and situations to draw from to create such a question (weak discursive relations). It, however, moves across into the purist quadrant, since there is a requirement that the solutions be within the remit of the course – that is, using the design equations and theory developed for reactors in this course.

Contrasting this assignment, against tutorials (which shape follows Figure 3), it is clear that the type of thinking asked of the students is subtly different – it is more open ended, more extra-referential, more self-reflective, which is clear throughout many of the quotes from the students, for instance from student 22:

> the task opened up creative thought process … engineering consideration had to be applied at all times to make the problem realistic

Students acknowledged the assignment's intention in generating conceptual understanding, through an open-ended approach:

Student 8: '… aided in gaining a more conceptual understanding of work … '

With some intending to adjust their study habits according to this insight:

Student 9: 'From now on I will try to understand the theory behind the calculations better'

One of the purposes in setting this type of assignment is to create an open-ended problem which requires an open-ended approach to demonstrating understanding. Several of the students picked up on this:

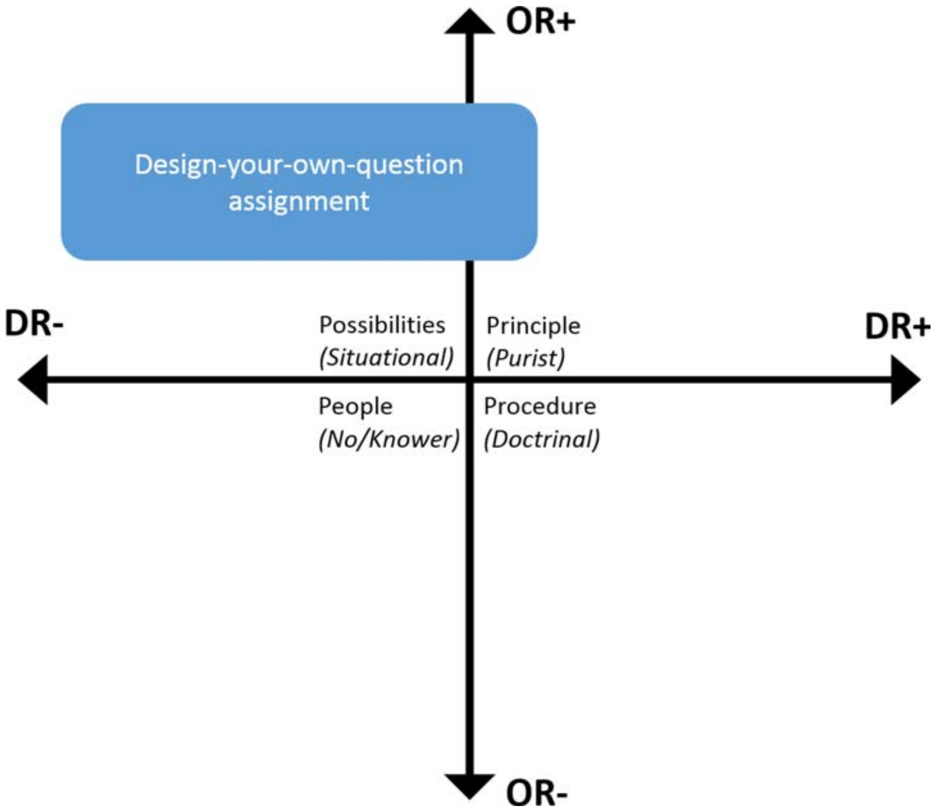

Figure 4. Epistemic plane detailing ontic and discursive positioning of the assignment.

Student 8: 'an open ended question … with the aim of applying the specific techniques taught in class'

A comment which sits squarely within the intended

This open-ended approach has implications on creativity, and thinking beyond the limits of the course material, which was explicitly acknowledged by several students:

Student 11: '… allows you to be creative and thoughtful … '

Where they understand that there is more to fully mastering the material than only doing problems, but that there are underlying principles which the students can grapple with:

Student 12: 'by not just going through problems but trying to engage with the question by asking what are they trying to test here … '

The open-ended nature highlights the multiple paths to solutions, and how the course content was more than calculation skill:

Student 6: 'there are many approaches one could take … the assignment did require students to have a good understanding'

Several students expressed the need to understand theory well, before you can even conceive of a question:

Student 5: '… having to set up your own question requires you to go more in depth into the work and understand the fundamentals really well'

And:

Student 10: 'to set a question you have to fully understand the problem and theory'

And some considered how setting an exam question requires potentially greater knowledge of the material than simply answering exam questions or doing practice examples:

Student 7: 'to set an exam question the conceptual knowledge of the material has to be sound'

An important aspect, which is needed in good curriculation, is combining topics to form a cohesive whole from the knowledge. Some insightful students noted this aspect, as an offshoot of the assignment:

Student 13: 'it allowed me to see the interconnectedness of the topics … I segmented my work a lot and did not realise that everything was related'

The reflection that the assignment stimulated in the students is apparent, with respect to this curriculum-connectedness:

Student 12: 'looking at it in retrospect helps with fitting all the chapters into the puzzle'

And even beyond the linking of subject material, to the more important link to problems from the world of work:

Student 14: 'it made me think of real-life scenarios and have to make questions out of them'

Of course, not all felt that the assignment was of use, many complained that it took too much time:

Student 15: 'did it to finish as quickly as possible'

Or acknowledged that because of time limitations they did not properly engage with the purpose of the assignment:

Student 16: 'I did not come up with an original question … .time constraints'

Some make the important point that an over-full semester can have negative consequences on learning outcomes:

Student 17: 'too many assignment can have the opposite effect than intended. Less time consuming assignments with a larger emphasis on understanding.'

Some considered that perhaps the assignment was too trivial:

Student 18: 'the calculations and problem solving were basic and nothing new, and the assignment did not offer assistance in developing these skills'

Or that the assignment was not of assistance in developing new connections:

Student 1: 'I feel it didn't develop and problem solving skills'

Some students were concerned that it was not sufficiently well defined:

Student 19: 'I felt we needed better guidelines to reach the wished outcome'

With several wishing for more detailed requirements, despite the open-ended challenge:

Student 2: ' … the exercise was too vague … '
Student 20: 'more guidelines as to how to approach the question and how it will be marked'

Another concern was that it was not sufficiently tied to real engineering problems:

Student 19: ' … didn't lead to deeper understanding of the work as it didn't apply the knowledge to a real world situation … '

These concerns are relevant and worth examining. With regard to the students' concern that the assignment was too trivial, or not tied to 'real engineering' this is perhaps a failure in communicating how exactly these calculations, methodologies and tools are used in reality. Chemical engineers, particularly those designing new plants, frequently use these equations, much as they are presented in the course material and examinations, to design real reactors. The students' attitude towards what they perceive as a trivial exercise demonstrates their lack of integrated knowledge – a link lecturers should assist in providing. The task was open ended: the students could have tied the question to the most concrete example, or the most complex, however not all students have developed this insight by this year of study. Nonetheless, rather than falling into a deficit discourse, perhaps this is an area where later, more explicit, discussion of question construction and inspiration might have improved further students' insight into how exam questions are intended to relate to industrial application. The commentary reminds the educator that links between theory and practicality are important. By doing so, you enable the student to build conceptual bridges between isolated concepts and their principle uses.

With regard to the concern that the assignment took too much time, the expectation was that the assignment should have taken roughly 6 hours to complete. Looking at Figure 5, which presents the students' self-reported time usage, it is clear that many say they spent more time on the assignment than that – concerningly up to 20 hours. Controlling expectation and communicating may assist with this over-zealous tail.

More concerningly, however, when examining the breakdown of what students spend their time on (Figure 6), on average students spent 25% of their time formatting the document they would submit. While there are report writing courses included in the curriculum, this course is not one – students are favouring form over substance here. One explanation may be that they have a thorough grasp of report writing, editing, and document curation, while they may not have such a thorough grasp of reactor design content, and so they focus on what they know. In future iterations of this exercise, the lecturer will explicitly point out this pitfall in the hopes of students' wasting less time on formatting, and focussing more fully on the objective: grappling with reactor design content.

Question 3 of the questionnaire asked the students 'Do you think exercises like this one will make you a better engineer?' The intention was to provoke introspection about the integration of curricular knowledge with vocational actions in real situations. 77% agreed that the assignment would make them better engineers, and commented on their perceptions of why, including epistemic conceptions, such as problem solving:

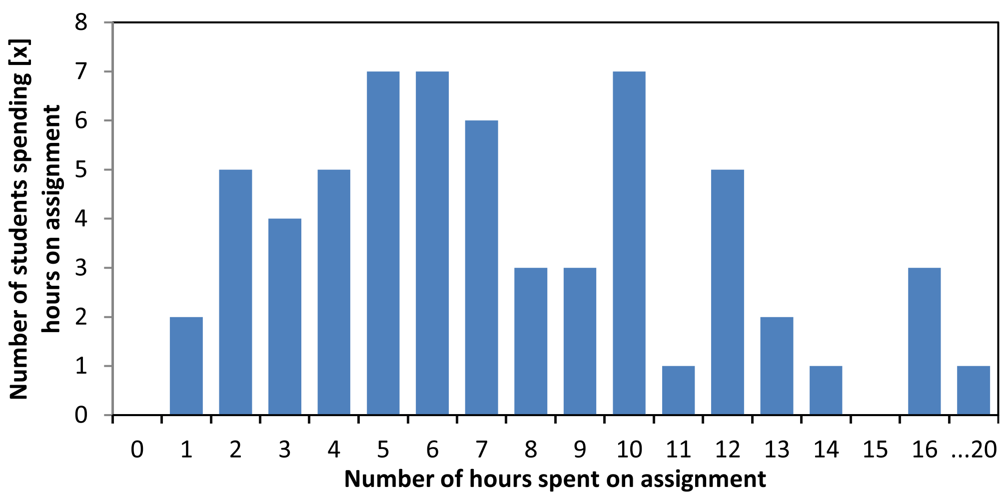

Figure 5. The number of students self-reportedly spending [*x*] hours on the assignment.

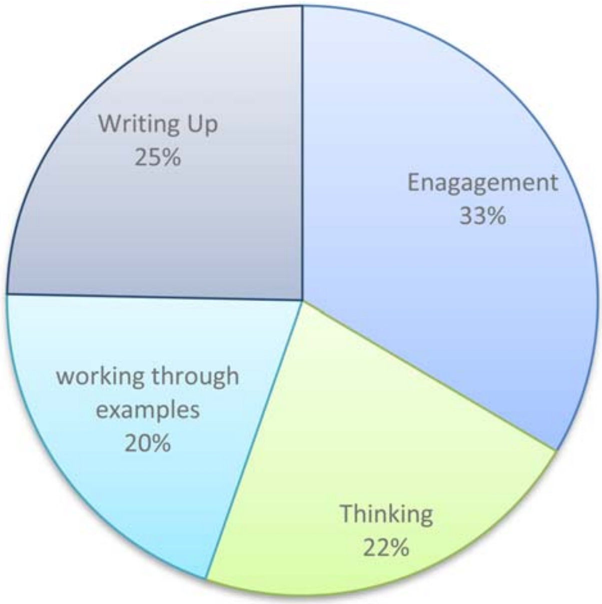

Figure 6. Self-reported averaged percentage time split between activities

Student 7: 'develop problem solving skills'

Or skill development with an eye to industrial application:

Student 21: 'creative thought leads to a better equipped engineer'

Others considered how the open-ended nature of the assignment stimulated a creative process, with application of engineering thinking throughout the process:

Student 22: 'the task opened up creative thought process … engineering consideration had to be applied at all times to make the problem realistic'

Or an explicit link to how work might be in industry:

Student 23: 'it gives an idea of how to work on a real life problem'

It is clear that many see the benefit in forcing open-ended engagement with the work, and allowing scope for developing problem solving skills or conceptualising 'real-world' problems in the context of the coursework. Further, several discussed more inter-personal insights, about workplace dynamics:

Student 7: 'one will only truly understand the work of someone else when you try to do it yourself. This would help in the workplace: relationships between employees'

Or an empathy with the work lecturers do:

Student 23: 'helped me get a better understanding of what my lecturers do'

With one commenting wryly on the challenge of exam setting:

Student 24: 'setting up a question was significantly harder than I initially thought'

With regard to the insight the assignment allowed on students' study habits, only 52% said they would 'adjust [their] learning and studying techniques' (Question 4 from the exit questionnaire).

This might be considered a significantly large percentage intending to adjust their study habits – over half! – but we have no follow on data to ascertain whether this intention followed through to action. Nonetheless, several students voiced insights into not simply following algorithmic or rote learning methods, and employing different study methods:

Student 12: 'shift my focus to trying to understand the work better … '

With a greater emphasis on understanding beyond rote learning:

Student 24: ' … more time will be spent … to get a better understanding … currently, I spend more time on remembering … '

Some considered how this theory might then be linked to the calculations:

Student 4: 'by doing this exercise I realised the importance of solid theoretical background and not just working out problems from tuts'

And with a stronger consideration of application of theory:

Student 25: 'previously I focussed on a lot of theory instead of focussing on how to apply the knowledge gained from theory.'

Several commented on shifting away from a 'memorise and replicate' approach to one which is more theory-bound:

Student 6: 'I will adjust my study methods … of understanding the work and better applying the theory … instead of just memorising and replicating the steps followed in tuts'

Or the introspection to realise that some work is more easily examined:

Student 26: 'asking myself how the examiner could ask questions rather than just memorising examples'

Gratifyingly students also voiced their appreciation for a 'different sort of assignment':

Student 28: 'thanks for the assignment. Enjoyed it a lot!'

Further implications

One limitation of this study, which the authors aim to elucidate in further work, is that there is no reliable quantified measure of students' understanding (i) pre- and post-assignment (ii) no benchmark with no assignment and (ii) on a longer-term basis, knowledge retention as a result of this assignment. So, while students do demonstrate their learning both in the written portion of the hand-in, noted by the facilitator, and in their responses the exit questionnaire, this cannot be considered to be sufficiently conclusive. Nonetheless, the response to the assignment appeared to indicate that the assignment assisted students in making linkages between the separate sections of work, and developing their understanding.

A second, and unintended, the outcome of the study was the generation of empathy from the students towards the lecturers. Many voiced that this was the first time they had considered what it was that lecturers aimed to achieve in setting exams, or considered just how much work it entails.

It is clear that an assignment such as this is a good way to round off formative assessment towards the end of a course. It requires integration of the material, and higher-order thinking than the algorithmic approach to problem solving favoured by students. However, the educator should beware, there are pitfalls in this methodology. Chiefly, several students blatantly took questions and solutions from other textbooks and presented the work as their own. There may be ways to circumvent or prevent such activities, but it is a concern. (Of course, there may nonetheless be some benefit to the students' understanding even in cheating the system in this way – they needed to find and understand the problem in the first place).

Finally, the assignment can be given as a 'work from home' problem, with the students requiring little supervision, and few resources. This lends itself well to our current circumstances (at the time of writing, we are in the throes of the COVID-19 crisis); this is a good assignment to be given during distance or online learning.

Conclusion

An assignment based on students developing and solving their own questions, related to the content of the course, was presented. Using data generated through voluntary student responses, it was seen that students, on the whole, found the exercise worthwhile: 72% of respondents indicated that the assignment improved their understanding, 75% thought the exercise would make them better engineers and even 52% claimed that the assignment spurred them to change the way they study. However, there was some push-back, with some students voicing concern over the time consumed by the assignment, or its open-ended nature.

One area which requires more thinking is that there is no reliable quantified measure of students' understanding (i) pre- and post-assignment (ii) no benchmark with no assignment and (ii) on a longer-term basis, knowledge retention as a result of this assignment. Perhaps collaborations between institutions teaching the same work might provide the controls needed to better grasp the effect of interventions.

An unintended consequence of this activity was the stimulation of empathy in the students, both for lecturers, and in consideration of engineers in the world of work. Reflection of this type is uncommon, and many students voiced that this was the first time they had considered lecturers as behind exams.

The sociological framework of Legitimation Code Theory was used to describe and visualise the cognitive motion and positioning experienced by the students through the assignment. The *status quo* of engagement was inferred to sit strongly within the doctrinal quadrant, with some reference to the purist quadrant – that is to say that students preferentially used a 'recognise and reproduce' methodology to problem solving. While the assignment itself was designed to sit more strongly in the situational quadrant – positioning bolstered by many student references to the 'open-ended' nature of the work.

Student question posing is positioned as a useful tool in stimulating better integration of disparate sections of work, especially in courses susceptible to algorithmic learning strategies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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