AAEE2018 CONFERENCE
Hamilton, New Zealand

A Heutagogical Approach for Teaching a Numerical Analysis Subject in Engineering

Peter To[1] (Peter, To); Rabin Tuladhar[1].
[1] *College of Science and Engineering, James Cook University*
Corresponding Author Email: peter.to@jcu.edu.au

STRUCTURED ABSTRACT

CONTEXT

As an advanced course in engineering education, Numerical Analysis is equipped with heavy mathematical and programming content. Therefore, it is often perceived as a challenging subject and is often taught in the final year as a selective subject. In a traditional way of teaching this subject, while doing tutorials and assignments all students are usually required to follow the same instructions and complete the same tasks. In this traditional method of teaching, students are not able to negotiate the learning process and may still lack understanding even when they complete the tasks.

PURPOSE

This study aims to develop a heutagogical approach for learning Numerical Analysis subject in Engineering. (Put the names of the subjects here) offered to undergraduate engineering students were chosen to trial this approach. The approach will give students ability to:

- Negotiate learning within the predefined frame of education.
- Develop deep learning of the theoretical concepts and be more proactive in the learning process.

APPROACH

Following heutagogical approaches were introduced into the two numerical analysis subjects EG3001 and CS4010. The class size for the subjects was around 25.

- Tasks and instructions are uploaded early so that students can have options in submission deadlines, i.e. which tasks will be completed first. They also are able to select the programming language for their simulation.
- Each student gets a unique problem, based on their student ID. They are also required to descriptively explain their code. This prevents code plagiarism and ensures the deep learning.
- Students can design their own problem and seek approval to use it. This enhances creativity and gives students more motivation to do the complicated works. The instructor specified some input data or requirements to ensure that the simulation is authentic.

RESULTS

A student survey has been undertaken and the feedback is positive. Although most of the students submit weekly tutorials in the predefined order, they appreciate the opportunity to submit tutorial not in order and the early upload of instruction. Due to the small class size with similar background of students, most students chose to select the same programming tool. Therefore, this alternation is not really necessary.

Students have no difficulties in doing their authentic problems and believe it helps them understand the concept better. Many students tried to solve their own problem with a higher complication. This definitely builds confidence for students in their future simulation.

CONCLUSIONS

Although heutagogical approach gave students ability to negotiate learning, not all of alternation were necessary. However, the heutagogical work can have significant impact in engaging students and enhancing their creativity. This will help students in preparing for real-life engineering problems.

KEYWORDS

Hetagogy, Numerical Analysis, Learning Negotiation, Engineering Education.

Introduction

The last two decades have seen several revolutions in education practice, which facilitate new principles of education. In Education 1.0, which lasted for millenniums, students gained knowledge passively through memorisation and experience. Then, internet-enabled learning in Education 2.0 allowed students to have self-paced study (Lytras et al., 2014), before Education 3.0 promoted learners to content creators (Harkins, 2008). Later, innovation was heightened in Education 4.0 thanks to advanced technologies. Nowadays, students do not have to follow a predefined pathway as in the traditional pedagogy. They can negotiate their learning and determine their own pathway, satisfying course criteria (Blaschke, 2012). For example, they can select which tools to use, which assignments to do, and when to submit in heutagogical approaches (Hase & Kenyon, 2013). This way, students are fully responsible for their learning and they are self-engaged in their self-determined learning (Samaroo et al., 2013).

However, the application of heutagogy in engineering education is limited, especially in some theory-heavy subjects (Gazi, 2014; McAuliffe et al., 2009). The main reason is the content sequence in those subject has very limited flexibility. For these subjects, students often prefer deductive learning, which tells them exactly what to do, rather than inductive learning, which requires deep understanding and allows creativity (Felder & Silverman, 1988). Hence, many theory-heavy subjects are taught in the traditional lecture-tutorial-based teaching mode.

Numerical methods, or sometimes in particular Finite Difference Method (FDM) and Finite Element Method (FEM), is a theory-heavy subject included in most engineering education programs. Because this subject requires some advanced mathematical understanding, it is often taught at the third or fourth year of a four-year program. It is also usually included as a core subject in postgraduate courses.

The authorial practice of teaching found that the current pedagogical approach did not release the full power of numerical methods to enhance creativity because students completed the same simplified assignments. In addition, some students are afraid of creating a new code for their own problems because it may contain some elusive bugs. This lack of confidence often leads to an undesired shallow understanding. Note that, it is a consensus among engineers that terrible mistakes in using software often come from the lack of basic understanding (McConnell, 1996). Therefore, there is a need for a feasible heutagogical approach in teaching numerical methods.

This paper presents a heutagogical approach in teaching numerical methods in two different engineering disciplines in the last two years at a university in Australia. The assessment comprises weekly tutorial submissions (30%), two assignments (20%), two quizzes (20%), and a final exam (30%). Students had options in each non-invigilated assessment if they wanted to create their own problem with instructor's approval or solve the given problems. They were also able to select their programming language and to negotiate their submission. The practice showed that students were well engaged and more confident in applying learned theories. This led to a better overall performance.

Heutagogical approach for non-invigilated assessment

Assessment design and approval

Weekly tutorial submission and assignments were the most interesting assessments of the subject, where students found the application of theories and power of simulation. This section describes three principles used in the design and approval of a new non-invigilated assessment in the heutagogical approach (**Error! Reference source not found.**). The principles are governed by two features: self-determined learning and strict quality control. The instructor should keep in mind these principles while designing an assessment to avoid potential problems in assessment approval and marking later.

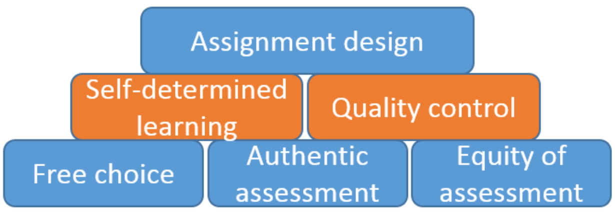

Figure 1: Principle of assignment design.

The first and foremost principle is the free choice, that is, students are able to select/negotiate almost everything from learning model to the submission due date (Figure 2). In terms of the learning model, students can select their pathway, that is, students who do not want to select the heutagogical approach still can complete their study in a traditional pedagogical approach. Therefore, all non-invigilated assessments in the subjects had a given problem, which provided some hints about the expected difficulty of the assessment for the creation of new authentic problems. Because both FEM and FDM were included in the subject, students could alternate algorithm if they are confident. Regarding tool selection, students were able to select software or programming language to use. The authors inherited teaching materials from a previous educator in C#. Later, the teaching materials with Matlab and Python is added by the first author as alternatives. Last but not least, students also had an ability to alternate their weekly tutorial submission sequence. For example, they could select to submit Tutorial 10 in Week 8 and Tutorial 8 in Week 10. This helped to avoid assessment congestion when many heavy assessments of different subjects were due at the same time. In addition, because blended learning approach is used in many Australian universities, teaching activities were recorded and subject materials were available through varied media (James Cook University, 2015; Oliver & Trigwell, 2005; Partridge et al., 2011; Taylor & Newton, 2013). Therefore, students in the subject also had the ability to select study time.

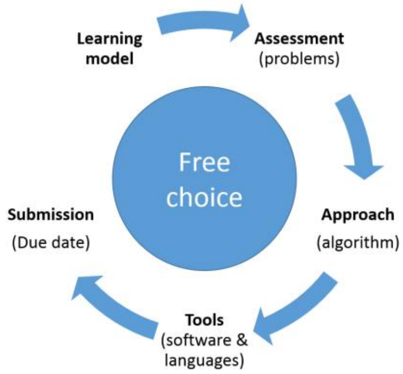

Figure 2: Free choices in the heutagogical approach

The second principle is the authenticity control. To enhance the creativity and ensure the authenticity, the provided problems were varied by student ID. This made all assessments authentic. Apart from the given problems, students always had an option to create their own authentic problems with the suggestion and approval of the instructor. Although students may not want any changes to maintain applicability, instructors should edit problems at some level if there is any concern about the authenticity of the solution. This way, students cannot use available solutions from the internet or elsewhere. Besides, students were notified that they could not have identical problems as it is plagiarism.

The third principle is the equity of assessment. The instructor must ensure the similarity of difficulty among problems. The authentic problems should not be easier than the given problems, and students can do more complicated problems if they are willing to. Sometimes, real-world problems need some essential simplification to be done within the timeframe of a university assessment. Further development can be done by students outside the education program.

As can be seen in the last two principles above, the heutagogical approach heavily depends on student negotiation. Therefore, the instructor must keep consistency in negotiation with varied students. A good practice is a table of assignment outcomes (Table 1), based on the targeted subject learning outcomes. An approximate estimation of the development level may make a better evaluation of the difficulty level.

Table 1: Checklist for problem approval

Assessment outcomes/requirements	Implication	Development level
Outcome 1 (e.g. time-dependent boundary condition)	Yes/No	(3 Construct)
Outcome 2 (e.g. Implicit algorithm)	Yes/No	(2 Apply)
Outcome n (e.g. featured thermal conductivity)	Yes/No	(1 Classify)

Note that, invigilated assessments, which took 50% of weight in the subject, were not modified because there was no time for negotiation during the examination. Although the alternation of exam questions was possible, it was not implied in the practice as it did not reflect the essence of heutagogy.

Assessment marking

A big challenge for heutagogical approach in engineering education is the marking process because it generates many unique authentic questions with uncommon solution. The conventional marking in heutagogial assessments may increase the workload significantly if all solutions are required to be made by instructors. Therefore, a new way of marking in the heutagogical approach was needed, especially for the weekly tutorials as they were numerous.

The new approach requires proposed features of the expected solution, not full solutions. If students receive marks for approach and accuracy in the traditional marking scheme, they receive marks for qualitative and quantitative features of their solution in the heutagogical approach. A good practice is a table for result comparison (Table 2).

Table 2: Result comparison

Qualitative marking	Expectation	Results
Feature 1 (e.g. stress concentration)	(Butterfly shape)	Match/Not
Feature 2 (e.g. response to moving load)	(Sagging)	Match/Not
Feature n (e.g. load supports)	(Rafter)	Match/Not
Quantitative marking	**Expectation**	**Results**
Feature 1 (e.g. double load)	(Reaction x2)	(Reaction x2)
Feature 2 (e.g. load on batten)	(deflection =0)	(deflection = 0.005)
Feature n (e.g. rotate force 90^{O})	(deformation vector rotates 90^{O})	(no rotation)

There is no bonus for problem creation because students already take advantage of creation to have familiar problems.

Efficiency

The efficiency of the new approach can be assessed by the proportion of students adopting this pathway, quality of submissions, and overall student performance, including the theoretical part.

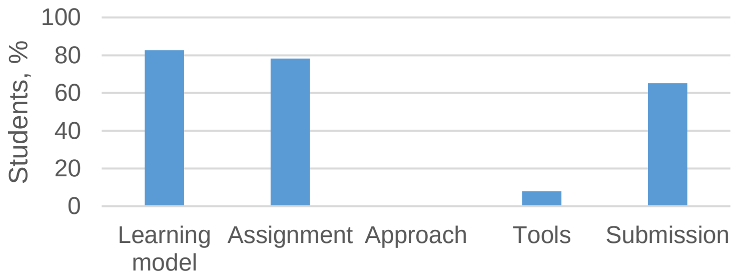

Figure 3: Proportion of students taking heutagogical opportunities

It is obvious that not all of the opportunities were necessary and, therefore, not all opportunities were taken. No student alternated algorithm (Figure 3). Switching between FEM and FDM was a challenging task for undergraduate students. In addition, most students selected Matlab because they learned it in some prior subjects. Note that, the subject was taught with C# before. Hence, if using C# would have been considered as the mainstream, most of the students had taken the alternative tool.

In contrast, students took opportunities of learning negotiation if needed. Only less than one-fifth of students selected the traditional pedagogical approach. Meanwhile, students were excited to create their unique authentic problems, most of which were more complicated than the solution in the traditional pedagogical approach. More than 60% of students negotiated their submission for at least one assessment. However, students did not stir up the sequence. They preferred to follow the predefined sequence as much as they could due to a strict sequence of theories.

Although the solution for the created authentic problems might not require a significant increase in workload (Figure 4), it was a good signal of competency that students were confident to apply theory to varied problems.

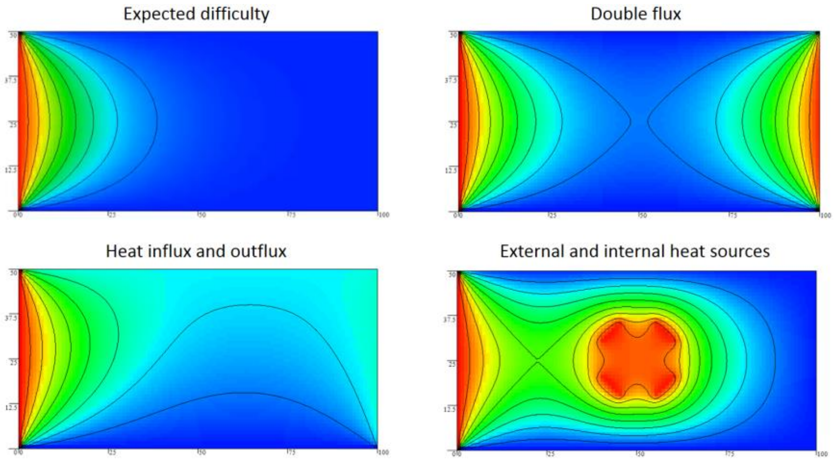

Figure 4: Typical submissions in a Finite Difference Method tutorial

Due to a limited number of available commercial software, most students selected ANSYS for their weekly submissions and the second assignment. However, it did not limit the creativity of students much. In fact, students had more ability to solve real-world problems (Figure 5) with small effort thanks to powerful features of the commercial software. The quality of submissions in the heutagogical approach was high and actually surprised the instructors.

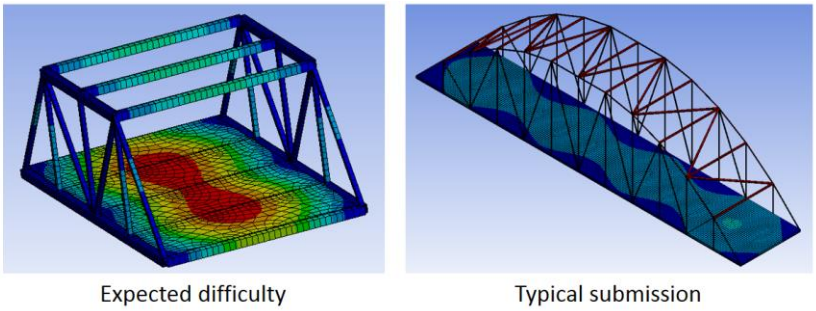

Figure 5: Typical submissions in a Finite Element Method tutorial

The last, but not least, assessing indicator of the heutagogical approach is the overall performance. There was a similarity between the overall student performance now and before without negotiation because these students had the same approach (**Error! Reference source not found.**). However, a closer look at the invigilated part shows that student who selected the traditional pedagogical approach had a slightly worse performance in comparison with the prior results. A feasible reason is that the majority of these students lacked confidence due to low GP. Meanwhile, students taking the heutagogical approach had much better performance and improved the overall performance of the subject. There is a concern about a misleading comparison because high-performance students were more confident and, therefore, selected the heutagogical approach. This way, the high performance came from students themselves, but not the new approach. However, the overall performance has been improved and students were engaged well throughout the course.

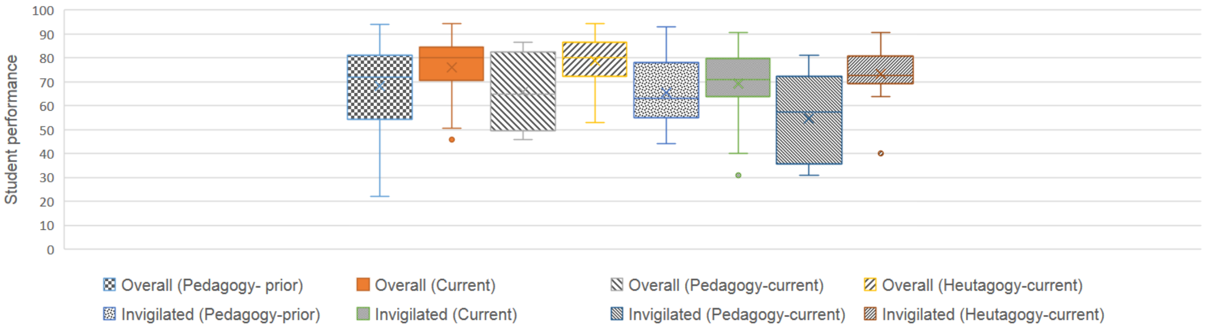

Figure 6: Student performance

Student feedback

Several anonymous surveys in a normal five-point scale were undertaken to see the appreciation of learning negotiation to student achievement. Although the surveys were voluntary, the response rate were about 50% and should be enough to be representative (Sivo et al., 2006).

The majority of students agreed with the importance of negotiation for all aspects, except tools (Figure 7) as not many students alternated them. About 60% of students appraised the creation of authentic problems and just about 5% of students found it not helpful. Although none of the students alternated the algorithm, roughly two-third of respondents thought it would be beneficial to do so. The open comments from some students revealed that they could understand the theory more when they gave an effort to alternate it, even without success. About 70% appreciated the ability to negotiate submission and a similar number of students found heutagogical approach important to their achievement.

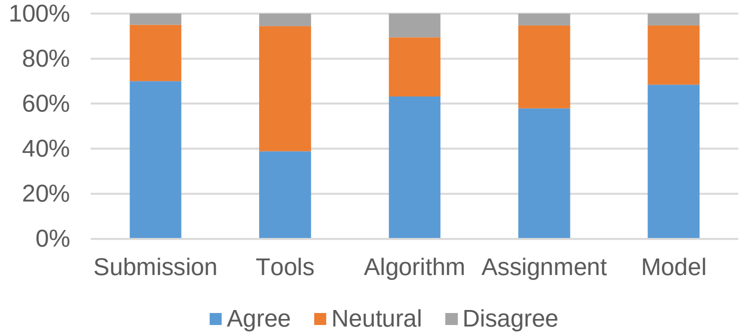

Figure 7: Opinions on the importance of negotiation to high achievement

In another survey on some experienced features of heutagogical approach, about 80% of respondents agreed that it facilitated quick learning (Figure 8). A potential reason might be the avoidance of learning a new programming language. A similar proportion of respondents experienced flexible timetable and roughly 85% of respondents had a self-paced study. This led to a surprising feedback that all responding students agreed indicated a deeper understanding with the heutagogical approach. Approximately three quarters of respondents thought the authentic problems were applicable. However, just over 60% of respondents circled that the approach enhanced critical thinking.

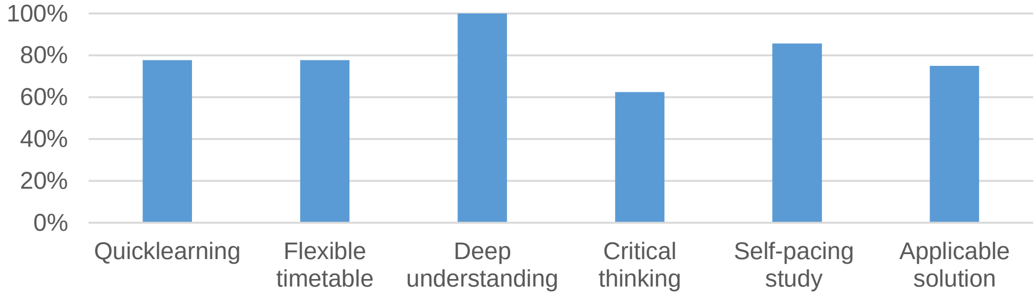

Figure 8: Agreement on features experienced in the heutagogical approach

Discussion

The heutagogical approach in teaching numerical methods has some challenges, which also open some opportunities for further development.

The biggest challenge in the current sight is the increase in workload. The instructor must be competent to provide adequate instruction in different programming languages and commercial programs. In addition, the new marking approach is still time-consuming because it required more steps than just comparing with a provided solution. While the traditional marking takes about several minutes for a weekly submission, the new marking varied widely and can take up to 20 minutes. This problem may be less serious for large classes with multiple instructors. Each instructor can be responsible for some tools and algorithms. However, it may be a trouble for small classes, where an instructor must take all the load. The practice showed that students in small classes have a similar background, and do not often alternate tools. Therefore, this alternation may be safely omitted. However, in case there is a need for alternation, joined subjects between universities may be an economical solution. As the subject is included in most, if not all, engineering education programs, instructors from different universities can share the workload in subject design and marking thanks to internet-enable learning. This may also enhance deep learning and research-informed teaching students can learn from different instructors, which is often an expert in a special method.

The second challenge in a heutagogical approach comes from its essence. When students have options to select, they may have a wrong choice if they have no idea about what they need. It stands to reason that the traditional pedagogical approach must not be eliminated in the heutagogical approach. Students should take the options only when they are confident.

The last challenge listed in this paper is the maintenance of equity of assignment. A heutagogical approach often strongly depends on the learning negotiation, which may be varied by instructors. Therefore, the assignment design must be done thoroughly so that it will limit the quality variation but not the creativity.

Conclusion

This paper presents a heutagogical approach in teaching numerical methods in engineering education. The approach gave students an ability to negotiate learning model, assignments, approach, tools, and submission. This enhanced student creativity and prepared them to real-world problems. To maintain the equity of assessment, instructors must follow some provided principles and criteria in design, negotiation, and marking. They should also edit the authentic problems to avoid plagiarism.

The efficiency of the heutagogical approach is assessed by the proportion of students taking opportunities, the quality of submission and the overall performance. About 80% of students negotiated their learning. As a sequence, the quality of submission and the overall performance have been remarkably improved. To reduce the workload for small classes, alternation of approach and tools can be safely omitted. The paper also proposed a joined subject among universities.

References

Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distributed Learning, 13*(1), 56-71.

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering education, 78*(7), 674-681.

Gazi, Y. (2014). Issues Surrounding a Heutagogical Approach in Global Engineering Educa-tion. *age, 24*, 1.

Harkins, A. M. (2008). Leapfrog principles and practices: Core components of education 3.0 and 4.0. *Futures Research Quarterly, 24*(1), 19-31.

Hase, S., & Kenyon, C. (2013). *Self-determined learning: Heutagogy in action*: A&C Black.

James Cook University. (2015). JCU Blended learning Guide.

Lytras, M. D., Zhuhadar, L., Zhang, J. X., & Kurilovas, E. (2014). Advances of Scientific Research on Technology Enhanced Learning in Social Networks and Mobile Contexts: Towards High Effective Educational Platforms for Next Generation Education. *J. UCS, 20*(10), 1402-1406.

McAuliffe, M., Hargreaves, D., Winter, A., & Chadwick, G. (2009). Does pedagogy still rule? *Australasian Journal of Engineering Education, 15*(1), 13-18.

McConnell, S. (1996). Avoiding classic mistakes [software engineering]. *IEEE Software, 13*(5), 112.

Oliver, M., & Trigwell, K. (2005). Can ‘blended learning’be redeemed? *E-learning and Digital Media, 2*(1), 17-26.

Partridge, H., Ponting, D., & McCay, M. (2011). Good practice report: Blended learning.

Samaroo, S., Cooper, E., & Green, T. (2013). Pedandragogy: A way forward to self-engaged learning. *New Horizons in Adult Education and Human Resource Development, 25*(3), 76-90.

Sivo, S. A., Saunders, C., Chang, Q., & Jiang, J. J. (2006). How low should you go? Low response rates and the validity of inference in IS questionnaire research. *Journal of the Association for Information Systems, 7*(1), 17.

Taylor, J. A., & Newton, D. (2013). Beyond blended learning: A case study of institutional change at an Australian regional university. *The Internet and Higher Education, 18*, 54-60.