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Applied logic: A Mastery Learning Approach Delivered Fully Online

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Abstract: This paper describes the move to a web-based mastery approach in an elective course on applied logic offered in a public university in northern Japan. This fully online course is designed using a content and language integrated approach so that students learn both the content and English at the same time. Logical and critical thinking is laden with complex concepts and technical terminology, and so to increase the rate and degree of comprehension, a mastery learning approach was adopted. An inventory of concepts, technical terminology and skills was created. The mastery list was sequenced into concept chains moving from lower to higher level concepts. Active learning activities were created for each concept chain. Criterion-based assessment checklists were created to enable self, peer and teacher assessment. Student response to the detailed mastery list was extremely positive. Using this mastery list students were better able to monitor their progress and identify which concepts to study.

Keywords: applied logic, online learning, mastery learning, digital artefacts

1. Introduction

This paper describes the move to a mastery learning approach in a fully online applied logic course. Uncritical readers may read persuasive texts and believe the veracity of news stories, the validity of conclusions in research articles or the benefits of products in advertisements. This course aims to provide students with the ability to evaluate such texts critically and not fall victim to persuasive arguments. Students are shown how to use logic to understand and evaluate written language. By the end of the course students should be able to: (a) identify arguments, conclusions, and reasoning; (b) identify common formal and informal fallacies; and (c) evaluate whether arguments are sound or cogent.

This paper is organized as follows. Section two describes the educational context and explains the difficulties that Japanese students found when studying logic in English. Section three shows how mastery learning can provide individualized learning, enabling learners to progress at their own rate. The following section details the course design, focusing on the syllabus and the online delivery systems. Section five describes and provides examples of the two types of course activities used, namely: process-orientated and product-orientated. Section six details the student, teacher and peer feedback received. Practical advice on adopting a mastery learning approach online is given in the conclusion.

2. Background

Applied logic is an elective course for third- and fourth-year students in a public university in northern Japan. This niche university is dedicated to computer science engineering and was the first university within Japan to specialize in computer education and research. All students are required to submit their graduation thesis in English and so in tandem with the focus on computing, there is also a strong emphasis on developing English language skills. The applied logic course is a two-credit course offered once per academic year. The course is delivered in one academic quarter, eight weeks, and comprises fourteen learning sessions followed by an examination. The course registration is capped at fifty students with enrolment vastly exceeding the number of available places.

2.1 Heavy content load

Over the course students are required to understand and be able to apply propositional logic, different types of reasoning, formal and informal fallacies and causality. As all students major in computer science and engineering, and study programming, most have some familiarity with formal logic. The complexity of both the subject matter and the terminology poses a significant challenge to many students. One issue is that students who miss or cannot understand concepts in a particular session tend to fall behind, since subsequent sessions build on concepts introduced in earlier sessions. This is akin to a student studying arithmetic failing to master single digit addition but progressing to double digit addition anyway.

2.2 Language

The applied logic course is designed using a content and language integrated approach so that students learn both the content and English simultaneously. Students not only need to be able to understand and apply their knowledge of formal and informal logic, but to be able to do this in English, which is an onerous task for many. Most students taking this elective course are much more comfortable writing computer code and solving calculus problems than communicating in English. Among the students there is a lack of confidence and a lack of willingness to communicate in English. The mean TOEIC score for this cohort was 390, which places them in the Common European Framework band of B2 intermediate user (Tannenbaum and Wylie, 2013). This score may reflect their receptive ability, but does not reflect their capacity to speak as few students are able to communicate smoothly.

2.3 Comprehensibility

A key problem is the extent to which students can understand the content of the class. According to Krashen (1985), comprehensible language input is when the level of input is slightly higher than the students' current level, which can be expressed algebraically as: $i + 1$
where i represents interlanguage and + 1 represents the next stage of language acquisition. However, based on student feedback from previous cohorts, the actual level is $i + \alpha$ where α is greater than 1. This means that the input tends to be incomprehensible without additional scaffolding provided by peers, dictionaries, and machine translation software.

3. Master learning approach

3.1 Theoretical background

In a mastery learning approach, students are required to master lower-level concepts prior to progressing to higher-level concepts (e.g. Bloom, 1971, 1985; Guskey, 2007; Slavin, 1987). In arithmetic and logic, should a student be unable to understand a foundation level concept (e.g. adding single digit numbers), then a more complex concept becomes impossible to master (e.g. adding double digit numbers). Students who are unable to understand the concepts introduced in the first session will have difficulty with those introduced in the second session. In short, failing at the first hurdle means that the second hurdle becomes impossible. This sequencing enables course content to be introduced at the point at which learning is most likely to occur. This sequencing, therefore, scaffolds learners through the zone of proximal development. Numerous researchers (e.g. Donato, 1994; Forman, 2008; Gibbons, 2009; Mariani, 1997) have applied Vygotskyan (1978: 86, cited in Yasnitsky, 2011) concept of zone of proximal development (ZPD) construct to language learners. Logical and critical thinking is laden with complex concepts and technical terminology. To increase the rate and degree of comprehension, a mastery learning approach was adopted. A mastery learning approach sorts and sequences content (skills, knowledge or behaviours) into bitesize chunks and then presents them in sequence. Mastery is evaluated using criterion-based assessments.

3.2 Practical application

In a mastery learning approach concepts are divided into a hierarchy of levels from the easiest to the most difficult. As shown in Figure 1, a five-step process is adopted.

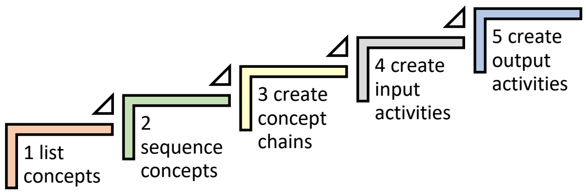

Figure 1: Development of output activities

To begin a mastery approach, an inventory of concepts, technical terminology and skills needs to be created. The mastery list is sequenced into concept chains moving from lower- to higher-level concepts. These items are then sequenced into a concept chain. An example of a concept chain in applied logic is: *true, false, truth value, declarative statement, premise, conclusion, logical indicator, inference, inference bar.* To understand truth value, it is necessary to know the two values of true and false. To identify premises and conclusions, it is necessary to know what a declarative statement is, and to know that only declarative statements carry truth value. Once the concept chains are created, input activities (e.g. reading, listening and watching) and output activities (e.g. speaking, writing and creating) are designed to provide students with opportunities to apply their newly-acquired knowledge. Output activities can be considered active learning (Bonwell and Eison, 1991). Activities incorporated into the course website include participating in opinion polls, working in pairs or small groups, and creating audio or video presentations. Active learning activities were created for each session. Criterion-based assessment checklists based on the mastery list were created to enable self, peer and teacher assessment.

4. Course design

4.1 Syllabus

The syllabus is divided into three blocks: identifying arguments, identifying fallacies and evaluating arguments. The course is front-loaded with technical terminology and logical concepts with the first five sessions being particularly demanding in terms of new terms and concepts. These terms and concepts are revisited numerous times throughout the course to reinforce and refine understanding and application (González Fernández and Schmitt, 2017). The course quickly moves from a knowledge-gaining focus to an application-focus with students being expected to apply their newly-gained knowledge. Initially this knowledge is applied to short simple texts, but as the course progresses longer and more complex texts are used. The list below provides an indication of the type of concepts covered:

- Reasoning: deductive, inductive, abductive, …
- Valid propositional forms: *modus ponens*, hypothetical syllogism,…
- Formal fallacies: affirming the consequent, undistributed middle term,…
- Informal fallacies: *ad hominem*, *ad populum, equivocation*,…
- Causes: proximal, distal, necessary, sufficient,…
- Paradoxes: Liar, Sorites, Heap,…
- Cognitive biases: anchoring, confirmation, framing,…

A flipped classroom was adopted to maximize the effectiveness of synchronous teaching sessions (Bergmann and Sams, 2012). This course is designed to function either fully online or in blended mode. In the blended mode, face-to-face class time is dedicated to discussion in pairs, groups or whole class. These discussions help to reinforce the students' understanding of logical concepts and test their ability to apply these concepts to various texts.

4.2 Open-access course website

A dedicated open-access course website was created using a mobile-first approach. A dark theme was chosen for the website in line with the results of a student preference survey. In earlier versions of this course, materials were delivered piecemeal, so all students studied the same concepts simultaneously. In this open-access version, students can access all learning materials from the outset of the course. This enables those students who want to progress faster or those who want to spend more time studying the materials in advance to do so. Concise descriptions of most concepts covered are now also available online in English and so students struggling to understand English can use software to simplify or translate the texts. By reading a translated or simplified version first, students are able to create a schema to help them comprehend the actual text.

4.3 Learning management system

The course website is used in conjunction with a learning management system (LMS) maintained by the university. Students are automatically enrolled in the LMS and all assessments and assignments are submitted through the LMS. Figure 2 shows a screenshot of the one question from a unit quiz, which is housed on the LMS. To enable students to check their mastery of concepts, a large question bank was created. In each session, quizzes are available for students. Students can take the multiple-choice quizzes multiple times. However, each time a quiz is initiated a different set of questions is generated from the extensive question bank. This provides students with multiple opportunities to achieve mastery.

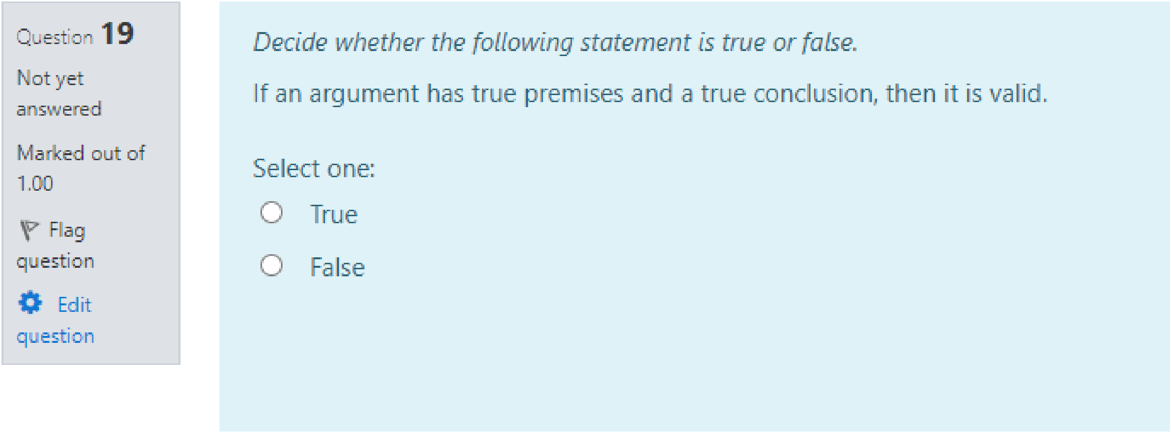

Figure 2: Screenshot of mastery learning question on validity and truth

5. Course activities

Course activities can be classified into two types: (1) process-orientated activities in which students are engaged in the process of learning, and (2) product-orientated activities in which the primary purpose is to create a digital artefact, such as a video file, as evidence of learning. In both sets of activities, open and closed questions are used to promote logical and critical thinking (Wilhelm, 2014).

5.1 Process-orientated activities

Process-orientated activities are used to get students to understand, explain, analyze and evaluate. Students are encouraged (but not forced) to work in pairs. Some examples of process-orientated activities include self-reflection, problem-solving, pairwork and groupwork.

The course website is divided into ten units or webpages. Emoticons are used to show students the type of activities (e.g. thinking, watching, reading). Each unit begins with a list of objectives and finishes with a revision slot (Blake, 2018). The objectives help focus students and align student expectations with the course objectives. The revision slot encourages students to evaluate the degree to which they have achieved the stated objectives. The revision activity can be in the form of a list of questions to answer, or problems to solve, or memory prompts, an example of which is shown in Figure 3.

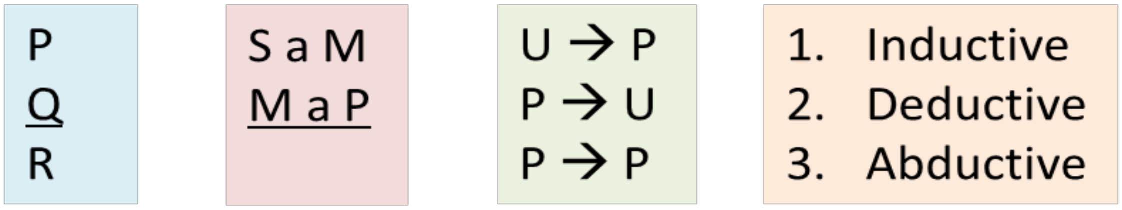

Figure 3: Revision prompts to enable students to recall types of arguments and reasoning

Group projects online help to create confidence and challenge (Lieberman, 2018). Asynchronous group work is challenging socially, administratively and logistically (Chang and Kang, 2016). When groups collaborate to create a written document using Google documents, it is easy for the tutor to monitor participation by checking the revision history (Lieberman, 2018). Wikis can be used in a similar manner. Figure 4 shows the diagram for an activity that can be used for pair or group work. This diagram of a causal network uses C1 to C4 represent causes and E1 for the effect. The diagram serves as a vehicle for students to recall terminology related to causality, such as root, distal, proximal, necessary and sufficient.

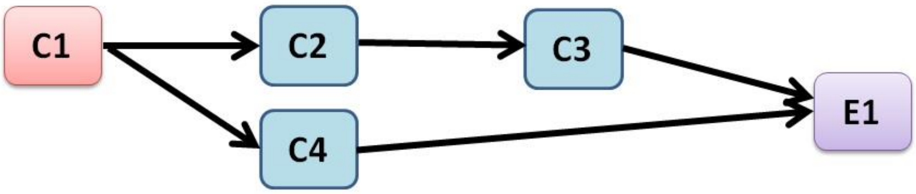

Figure 4: Diagram to enable recall of vocabulary to describe causes

5.2 Product-orientated activities

Each product-orientated activity results in the creation of a digital artefact. Digital artefacts are digital files produced in educational settings (Barton and Collins, 1997). The submitted software, reports and videos are, therefore, digital artefacts. These are stored as plain text, rich text, audio or video files. Being digital, these artefacts can be edited, adapted and reused. This means that subject to permission, an artefact submitted for an assessment or assignment can be reused as course material. It is time-consuming for a teacher to create fifty examples, but setting fifty students the task of creating one example, not only produces fifty examples quickly, but provides students with a motivating purpose for creating a text for a real audience rather than simply producing material for assessment purposes. Axiomatically, the examples need to be checked to provide feedback to its creator and to identify which materials can be used as teaching material. Examples of student-created text files are given below.

Arguments and analyses created by students to show their understanding of different types of arguments and fallacies can be repurposed. Figure 5 shows a student-created argument that is repurposed as an assignment while Figure 6 shows a student-created analysis of an argument taken from a cartoon created during the run-up to the 2016 United States presidential election.

Argument 1 *Evaluate and name the following short argument. Identify the conclusion, evaluate the truth value of the statements and validity of the argument. If a fallacy is present, name it.*
If Java language is running, then the function of C++ language is used. If the function of C++ language is used, then we can utilize C language. Therefore, If Java language is running, we can utilize C language.

Figure 5: Student-created assignment**.**

Students also created audio explanations in both English and Japanese for each of the 108 concepts covered in this course. These will be hyperlinked to the terms in the course website so future cohorts can access these on demand. Some video explanations have also been created. The most popular videos are animated slideshows with narration.

A novel learning activity is annotating logical features using tailormade html-like markup tags. Students can submit their annotated texts into an online argument analyzer, which visualizes the tags and displays explanations of the features (Blake, 2019).

If Hillary is speaking, she is lying.
She is lying.
Therefore, she is speaking.

Structure:
Premise 1
Premise 2
Conclusion
The conclusion follows the logical indicator *therefore*.

Reasoning:	deductive
Truth value:	uncertain
Evidence:	none
Formal fallacy:	affirming the consequent
Proof of fallacy:	P = Hillary is speaking Q = she is lying. P --> Q Q P

This argument is also a form of *ad hominem* or personal attack.

Figure 6: Extract from teaching materials inspired by student work

6. Course evaluation

Student, peer and teacher evaluation was carried out. Student evaluation of the new course format was positive. In formative student feedback questionnaires administered through the LMS, students stated that they liked the following:

- Paired reviews, e.g. co-creating a review
- Clarity of the 108-item mastery list

- Multiple chances to obtain 100% on assessments
- Not having to retake tests once a concept is mastered
- Ability to self-evaluate using checklists

Feedback from the peer evaluation included the suggestion to ensure that all terminology is explained on the course website in text form to ensure students can easily source translations. Other comments related to typographic and spelling errors that are easily addressed.

For the course tutor there was a considerable upfront time cost in terms of creating the system and developing the online materials. The burden of rapid materials creation was ameliorated somewhat by incorporating student-created digital artefacts. However, this still incurred a significant time cost to check the quality of the content, standardize the format and upload the materials. As the course is now fully online, in future courses the tutor can choose to deliver classes face-to-face or online without incurring any significant time cost.

7. Conclusion

In summary, the mastery learning approach is based on pedagogically sound principles, but the operationalization is challenging logistically and technologically. The rapid development and deployment of an online course was made possible by carefully structuring student assignments so that the materials created in earlier units could be transformed into activities in later units or in the next iteration of the course. Based on the lessons learned, eight suggestions for anyone designing an online mastery learning course using student-created digital artefacts are listed below.

1. Create a mastery list of the knowledge, skills and behaviours required.
2. Provide measurable objectives which can be tested.
3. Get students to create artefacts as assignments or assessments.
4. Write clear rubrics to get the best quality artefacts.
5. Assess artefacts using clear criteria.
6. Create materials and tests from artefacts.
7. Include a unit review for students to check their understanding themselves.
8. Provide a running tally of concepts covered, e.g. 52 out of 108 concepts.

References

Barton, J., & Collins, A. (1997). *Portfolio Assessment: A Handbook for Educators. Assessment Bookshelf Series.* New York: Dale Seymour Publications.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day.* Arlington, VA: ISTE.

Blake, J. (2018). Sound start, firm finish. *English Teaching Professional, 116*. 17-18.

Blake, J. (2019). Argument Analyzer: Visualizing and explaining logical arguments in context. In Chang, M. et al. (Eds.) *Proceedings Volume II of 27th International Conference on Computers in Education, (pp. 308 - 313).* Taiwan: Asia-Pacific Society for Computers in Education.

Bloom, B. S. (1971). Mastery learning. In J. H. Block (Ed.), *Mastery learning: Theory and practice (pp. 47–63).* New York: Holt, Rinehart & Winston.

Bloom, B. S. (1985). *Developing talent in young people*. New York: Ballantine Books.

Bonwell, C.C. & Eison, J.A. (1991). Active Learning: Creating Excitement in the Classroom. *ASHE-ERIC Higher Education Report 1.* Washington, D.C.: George Washington University.

Chang, B., & Kang, H. (2016). Challenges facing group work online. *Distance Education, 37*(1), 73-88.

Donato, R. (1994). Vygotskian approaches to second language research. In J.P. Lantolf & G. Appel (Eds) *Collective scaffolding in second language learning. (pp.33-56).* Ablex: Westport, CT.

Forman, R. (2008). Using notions of scaffolding and intertextuality to understand the bilingual teaching of English in Thailand. *Linguistics and Education, 19* (4), 319-332.

Gibbons, P, (2009). *English learners, academic literacy, and thinking: Learning in the challenge zone.* Portsmouth, NH: Heinemann.

González Fernández, B., & Schmitt, N. (2017). Vocabulary acquisition. In Loewen, S., & Sato, M. (Eds.), *The Routledge handbook of instructed second language acquisition,* (pp. 280-298). Taylor & Francis.

Guskey, T. R. (2007). Closing the achievement gap: Revisiting Benjamin S. Bloom's "learning for mastery." *Journal of Advanced Academics, 19*, 8–31.

Lieberman, M. (2018). Online students don't have to work solo. *Inside Higher Ed.* Retrieved from: https://www.insidehighered.com/digital-learning/article/2018/04/25/group-projects-online-classes-create-connections-and-challenge.

Krashen, S. D. (1985). *The Input Hypothesis: Issues and Implications.* New York, NY: Longman.

Mariani, L. (1997). Teacher support and teacher challenge in promoting learner autonomy. *Perspectives, a Journal of TESOL - Italy 23*(2), Retrieved from: http://www.learningpaths.org/papers/papersupport.htm

Slavin, R. E. (1987). Mastery learning reconsidered. *Review of Educational Research, 57*, 175-213.

Tannenbaum, R. J., & Wylie, E. C. (2013). Mapping TOEIC® and TOEIC Bridge™ test scores to the Common European Framework of Reference. *The research foundation for the TOEIC tests: A compendium of studies, 2*, 6-1.

Wilhelm, J. D. (2014). Learning to love the questions: How essential questions promote creativity and deep learning. *Knowledge Quest, 42*(5), 36.

Yasnitsky, A. (2011, June). Vygotsky circle as a personal network of scholars: Restoring connections between people and ideas. *Integrative Psychological and Behavioral Science, 45,* 422 https://doi.org/10.1007/s12124-011-9168-5.