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Online quiz methods for remedial learning in chemical engineering

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ABSTRACT

Online quizzes with feedback and retake options can be effective as a remedial learning strategy in a curriculum with sequential courses that rely on prerequisites. Use of groups of two to three students on these quizzes facilitates the learning process by creating an environment where students share their knowledge and understanding. Group activities can extend to sharing and building upon the students' strategies for locating and using free online learning resources. This paper is on methods of preparing online quizzes for remedial learning including structures of questions suitable for remedial learning and approaches to attain analysis and evaluation learning levels for a course in reaction engineering.

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1. Introduction

Advanced courses in sequential curriculum should require knowledge, understanding, and skill sets which are acquired from course prerequisites. It is essential that these capabilities are met, otherwise, students' academic weaknesses can lead to systemic lowering of the capabilities of a program's graduates. Also, from the perspective of teaching, it is important for all students to have similar capabilities so that lecture materials are presented at the right level.

This paper considers courses in chemical engineering thermodynamics and chemical reaction engineering; courses that are typically 5th to 7th semester courses in a chemical engineering curriculum. Typical expectations on students entering these courses are summarized in Table 1. Listed in this table are topics typically required from these courses and which should have been learned by the students in prerequisite courses.

A hybrid format in which about 33% of the course includes use of online materials is particularly conducive to online quizzes with feedback and retake options. Such quiz-based processes are advantageous because these online processes: a) do not consume lecture time repeating content already covered in prerequisites, b) will not "bore" students who successfully learned and retained content from prerequisites, and c) can be more decisive in bringing

the entire class to a common level on which lecture content can be spent.

This paper presents an approach to remedial learning with the use of online quiz questions, quiz questions' feedback, and the opportunity to retake the online quiz. Additionally, an emphasis is placed on methods of preparing online questions for purposes of remedial learning.

Remedial learning through online quizzes can be particularly effective for the following reasons:

- Online quiz questions can engage students in learning more effectively than lectures and at multiple scheduled times throughout the week.
- Online feedback (including correct answers and hints) for incorrect answers provides students the opportunity to verify corrected methodologies before retaking quizzes, providing just-in-time learning.
- Just-in-time learning consumes little time of the more-learned students with the repeat-exposure providing improved retention.
- Online quizzes can provide group learning environments where colleagues have a common goal to help each other learn; more-learned students can attain higher levels of learning by helping other students learn the content.
- Remedial quizzes can progress to higher levels learning (e.g. evaluation level) in a familiar format (a continuation of the same format as initial quizzes intended primarily for remedial purposes).

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Table 1

Q5 Example of topics for remedial learning in two undergraduate chemical engineering courses.

Course Title (prerequisites)	Prerequisite Topics (remedial learning topics)
Chem. Eng. Thermodynamics (aka Applied Physical Chemistry)	
○ Physical Chemistry	• Unit conversions
○ Physics	• Temperature conversions
	• Calculation of Force, Work, and Energy
	• Pressure (hydrostatic, ideal gas law, gauge)
	• Antoine equation
	• Application of Energy Balance
Chemical Reaction Engineering	
○ General Chemistry	• All Prerequisite Topics of Chem. Eng. Thermo.
○ Calculus and Ord. Diff. Equ.	• Atomic Balances (Reaction Stoichiometry)
○ Mass & Energy Balances	• Reaction conversion, selectivity, and yield
○ Chem. Eng. Thermodynamics	• Analytical solutions to “ x'' dx” integration
○ Transport Phenomena	• Trapezoidal Rule, Euler's Method

• Part of the remedial learning process can involve using, and learning how to effectively use, online resources (e.g., Wikipedia) that are more-readily available than textbooks to the students for general use in their careers.

The last of these is particularly important since it can be cumbersome for students to rely too heavily on their textbooks to solve problems.

1.1. Background

Several studies have applied computer learning systems for remedial learning. These computer systems were designed to determine learning deficiencies and misconceptions of individual students and suggest remedial learning materials based on the individual's learning profile.

In some studies, conceptual graphs were used as basis in determining learner's deficiencies (Chen, 2011; Chu et al., 2010; Jong et al., 2004; Panjaburee et al., 2013; Ting & Kuo, 2016). A conceptual graph shows concepts arranged in a hierarchical structure where relationship and association of concepts are shown through connecting nodes. It is a schematic representation of knowledge structure which has been traditionally used as a guide in teaching and learning complicated topics. Learner's deficiencies are determined by comparing their individual conceptual graphs to an expert's conceptual graph. Remedial learning path and materials are then suggested based on these learning deficiencies.

While a conceptual graph is a good basis for diagnosing learner's deficiencies, remedial learning can be implemented without using conceptual graphs. Other studies successfully used alternative methods aside from using conceptual graph as basis for remedial learning. Chen (2008) used genetics-based personalized e-learning system to generate the learning paths according to incorrect testing responses in a pre-test. Lin et al. (2016) used fuzzy expert system to determine the amount of remedial materials given to students based on their test results. Hsieh et al. (2013) used a system that adopted the fuzzy logic theory to create a learning path for individual learners and choose the remedial materials according to learner preference.

All of these studies required the use of computer software in the diagnosis of an individual's learning deficiency and in the application of individual remedial learning solution. However, these computer systems are not readily available.

An alternative remedial learning system is proposed in this paper where remedial learning is pursued through online quizzes.

Remedial learning is simplified when only two concept nodes are involved, particularly when remedial learning is applied sequentially. In this case, remedial learning topics are not taken from the most basic courses but only from prerequisite courses. As exemplified in Table 1, remedial learning topics, as determined by the teacher, were taken from prerequisite courses. To eliminate the need for individual diagnosis of learner deficiency, online quizzes are given to all students, providing remedial learning to low-achieving students and mastery learning for high-achieving students. In this method, online quizzes become a form of online formative assessment.

Online quizzes created in a format compatible to Learning Management Systems (LMS) like Blackboard, Canvas, and Moodle could be used as formative assessment tool within the context of remedial learning to develop a level of mastery of the fundamental topics required in an engineering course. In a study by Marden et al. (2013), the quiz model that allows multiple unsupervised and untimed attempts has the strongest formative focus on students in a physiology class. This quiz method was associated with a significant increase in mean examination performance. Although the use of multiple choice questions in the study could be limiting to lower-level learning (remembering and understanding), this quiz type proved to be useful in a physiology course where the study was applied. However, in engineering courses, higher-level learning (application, analysis and evaluation) questions must be emphasized since engineers mostly work with optimization and design. In addition, the use of higher-level questions can provide an efficient way of learning both higher and lower knowledge levels, as demonstrated in a study of Jensen et al. (2014). The study, as applied in a biology course, suggested that exams requiring higher-level learning (application, analysis, evaluation) encouraged deeper processing of information and better memory for the core information (memorization and understanding).

According to Gikandi et al. (2011), three fundamental issues must be considered in online formative assessment to realize its desired outcome: validity, reliability and dishonesty. Validity is the degree at which the assessment promotes further learning; reliability is a measure of the sufficiency of the assessment on the knowledge level being developed; while dishonesty could stem from an ineffective assessment which could mean poor levels of validity and reliability (Gikandi et al., 2011). In this paper, validity and reliability are addressed by creating quiz questions that can be varied multiple times and by creating questions with knowledge-level progressions (up to evaluation level) in a format that would require a single numerical value as answer. The latter is a unique approach in creating online quiz questions that has not been attempted in existing literature.

This paper is written for a remedial learning process that is part of a blended course where online quizzes are part of weekly activities throughout the semester. Initially, the online quizzes would have a high remedial learning content, while quizzes later in the semester would have higher contents of material introduced in the course and higher learning levels for the remedial content.

2. Discussion

A critical aspect of using online quizzes for remedial learning is immediate feedback with the opportunity to learn how to correctly solve the problem followed by a retake of the quiz. This process is illustrated by Fig. 1.

The process starts with the first attempt at the quiz. The quiz may be an individual or group activity. Feedback is given after each attempt of the quiz is submitted. The feedback shows the correct answer for each item. Also, hints toward approaches to solving the problem may be provided as feedback when the answer is incorrect.

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