Work in Progress – Implementing a Differentiation Framework into Freshman Engineering Classes

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***Abstract* - A Differentiation Framework has been developed at the University of Mississippi to address widespread student variation at freshman level in chemical engineering. It is hoped that implementation of this framework will increase student retention and maximize *all* students' learning outcomes. The framework consists of five broad (and usually progressive) categories that include understanding student need, providing students with challenging activities and eventually creating independent learners. It has been based on a detailed review of differentiation in the literature, mostly centering on educational instruction within the secondary school sector. While it is a common pedagogical technique used in K-12 environments, only a handful of studies appear in the literature regarding use of these techniques at higher-education levels. This is despite the fact that there are large drop-out rates of students at freshman level, and particularly in STEM-related courses. Differentiation techniques have proven very successful in many K-12 settings, and it is expected that this success can be transferred to freshman-level (and potentially beyond) chemical engineering courses. These techniques are to be trialed in ChE101 – Introduction to Chemical Engineering.**

Index Terms – Differentiation framework, Differentiated instruction, Independent learners.

INTRODUCTION

Differentiated learning is commonplace in K-12 educational settings, endorsed by some state education departments to encourage teachers to differentiate their classes. For example, the Department of Early Education and childhood Development in Victoria, Australia (DEECD) states that "…the teacher proactively plans and carries out varied approaches to content, process, and product in anticipation of and response to student differences in readiness, interest, and learning needs" [1]. Tomlinson [2]-[3] suggests that teachers focus on key concepts of the topic; enable critical thinking of students; engage all students in all lessons via a range of active learning strategies; and provide a healthy balance of student- and teacher-choice tasks to create a differentiated class. These general themes are also echoed by Small and Lin [4]. Effective implementation of these strategies results in the teacher creating 'real learners', those who have mastered the 'art of learning'. At this point the teacher becomes more of a guide or facilitator rather than an access point for knowledge dissemination.

Various strategies can be implemented to assist in creating a differentiated classroom. Some examples of these include experiential learning (experience, reflect, think, act) [5]; use of Vygotsky's constructivist theory and creation of the Zone of Proximal Development (ZPD) [6]; Bloom's taxonomy to structure lower and higher order thinking [7]-[8]; and Gardner's somewhat controversial multiple intelligences [9]. Piaget's development theory describes four progressive stages of cognitive development, believed to have been acquired by a child of 16 years (sensory-motor, pre-operational, concrete operations, formal operations [10]).

Differentiation strategies have been well-tested in K-12 settings [11]-[14]. While the effectiveness and success of this technique is sound, is this technique applicable in higher education settings? Do our (typically) young-adult students require similar assistance as children to progress their learning? Piaget's development theory essentially assumes they don't, as his theory is based on biological development such that a child of 16 years should have mastered cognitive development. Singer and Revenson [15], however, further qualify these stages by stating that each child progresses at different rates. Studies several decades ago [10] found that up to 50% of students entering college were still at the concrete operations stage, and more recent studies [16] now focus on post-Piagetian theory, which extends the categories beyond formal operations stage. It is therefore likely that a student has not acquired the necessary thinking tools and moral judgement to equip them for adult life by age 16. In a local context, the State of Mississippi was ranked 50th in the nation in 2014 with respect to K-12 education [17]. The University of Mississippi's admission standards are consequently relatively low to accommodate the large disparity of student-readiness of incoming students [18], although at the same time, high-performing students are attracted to the Sally-McDonnell-Barksdale Honors' College program, considered to be one of the best in the nation [19]. These large differences between student readiness, study habits and learning preferences indicate a need for differentiated instruction, particularly at freshman level and in similar lower-performing states.

Chamberlin and Powers [20] implemented a differentiated curriculum for first year mathematics students in the Rocky Mountain region, USA, and found clear improvements in student content knowledge and their

perception of learning compared with a control group. Konastantinou-Katzi, Tsolaki, Meletiou-Mavrotheris and Koutselini [21] also created a differentiated program for 27 first year engineering mathematics students. Importantly, they reported 13 more A-grades and 15 less 'C-or-below' grades upon completion of their differentiated program. These two studies demonstrate the same successes as K-12 education of a differentiated program in higher education.

This paper discusses the planning required to implement differentiated learning into ChE101 – Introduction to Chemical Engineering, as well as the development of a suitable differentiation framework for use by all post-secondary educators, particularly in STEM-based courses.

METHODOLOGY

A systematic review [22] was followed to adequately assess the differentiated literature in primarily upper secondary and post-secondary settings and in STEM-based curricula where possible. This review enabled the development of an initial differentiation framework consisting of five broad categories. Additionally, a preliminary User-Guide for students on 'learning how to learn' and a differentiated curriculum for ChE101 has been developed. This will be delivered in Fall, 2016, and conducted as an Action Research study to enable modification of the framework and User Guide into their final form. A User Guide for instructors will also be prepared to provide guidance in developing differentiated curricula.

RESULTS TO DATE

I. Development of Initial Framework

Results from the systematic review identified five key 'differentiation principles' (DP) that broadly describe a differentiated classroom [14] (Table 1), with a more detailed description of each DP in Table 2. This framework will be expanded to include detailed instructions in the form of a User-Guide for educators wishing to devise a differentiated curriculum for their courses.

TABLE I
THE FIVE DIFFERENTIATION PRINCIPLES (DP1-5)

DP	Title Description
1	Understand student needs and learning styles
2	Focus on key concepts and provide multiple approaches to learning
3	Provide challenging learning experiences within each student's ZPD [6]
4	Foster collaboration between students and faculty
5	Create independent learners and student ownership of learning

II. Development of Preliminary Student User-Guide

A preliminary Student User-Guide was based on the same five DP as outlined in Tables 1 and 2, to be used as a tool for student learning [14]. It is important to make the connection between both student and instructor benefit from these differentiation principles. In theory, students would be developing their own understanding of how they learn to reach the ultimate goal of an independent learner, whilst participating in a differentiated curriculum delivered in such a way as to maximize their learning outcomes.

TABLE 2
BRIEF SUMMARY OF THE DIFFERENTIATION PRINCIPLES (DP)

DP	What the DP means	Key characteristics of DP
1	Need to determine entry-level student ability for course; preferred learning styles; needs and issues throughout the course with respect to learning	Assess students' prior knowledge; provide questionnaires for feedback
2	Decide on the key concepts of the course and minimum requirements; deliver learning via a range of learning activities based on feedback from student preferred learning styles	Identify key concepts; provide innovative and engaging class activities for students to learn content
3	Provide in-depth and challenging activities that promote student growth to their next level of learning; develop critical thinking and problem-solving skills	Bloom's taxonomy; simulations; group projects; experiential learning
4	Provide group work to prevent student isolation; foster collaboration and trust among students; and implement a collaborative learning approach between students and faculty	Instruction on working in groups; provide group projects and tasks; become facilitator to students
5	Encourage students to become independent learners such that they can confidently approach any new task in the knowledge that they will master the concepts.	Project work; independent studies; student-choice; novel assessments

The Student User-Guide consists of five sections reflecting the five DP. In section 1, students are encouraged to reflect on their current strengths and weaknesses, and what they could do to both enhance their strengths and address their weaknesses. Students are also persuaded to identify their preferred learning styles, and identify *why* these particular styles enable them to maximize their learning. Section 2 invites students to identify the key concepts within their subjects, and to develop a study plan in order to successfully ensure they are competent with these themes. Tips are provided on how to find additional assistance for students who have not yet mastered the key concepts, and also for those wishing to extend their present knowledge of the topic. Students are also guided on becoming 'mentally ready' to commit to engagement with their studies, and look for benefits in learning approaches that are not their preferred style. Activities are provided to find ways in which they could convert content delivered in less-engaging ways into their preferred style. In Section 3, students are taught how to structure their learning primarily according to Bloom's taxonomy [8], where they learn definitions and basic understanding first before approaching activities that require higher-order thinking. They are provided with problem-solving and critical thinking tools to undertake more challenging tasks with success. Section 4 provides detailed assistance to enable students to learn how to work in teams [23]. This also includes conflict resolution that inevitably occurs in teams and ways to develop true collaboration for the benefit of all. Finally, in Section 5, students are asked to reflect on their understanding of how they learn, and come up with a detailed and unique set of tools that they can use to approach any new learning.

III. Creation of Differentiated Curriculum for ChE101

A tentative curriculum for ChE101 has been created, using the DP defined earlier. Specific activities have been developed for each of the DP, and will be implemented throughout the course. Of particular note are questionnaires and pre-knowledge quizzes (DP1); plant tours, design project and differentiated tutorial sheets (DP3); team-building skills to undertake project work in groups (DP4); and an independent study on a global technical issue (DP5). In all cases, various support-activities in the Student User-Guide as detailed above will equip students with appropriate skills to work towards becoming independent learners. Technically, students will gain in-depth understanding of what chemical engineers do, learn basic engineering calculations, and get an appreciation of chemical engineering design. The plant tour will provide experiential learning of the working environment chemical engineers typically encounter.

FUTURE WORK

Work intended to progress this educational research includes the implementation of a differentiated curriculum of ChE101 in Fall, 2016, with modifications and refinements of the Differentiation Framework based on the results of this action research. The User-Guide for students will be further refined, and a similar User-Guide for instructors will also be written based on the five differentiation principles. This work will then be tested on a larger scale in a number of freshman classes, and potentially extended to sophomore levels and those where wide variability within a class is identified.

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