We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Chapter 1

Utilizing a Differentiation Framework, Piagetian Theories and Bloom's Taxonomy to Foster Experiential Learning Activities in Chemical Engineering

Brenda Hutton-Prager

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75646

Abstract

This chapter will explore the development of laboratory experiments and analysis for undergraduate chemical engineering students, by utilizing a differentiation framework specifically adapted for university-level education. The differentiation framework explores the relationship between Piagetian and post-Piagetian *thinking skills* with differentiated *learning skills*, demonstrating links with Bloom's taxonomy and experiential learning theories. Experimental activities developed within such a framework will allow *all* students to participate fully in the learning experience intended, as they will be given opportunities to reflect on the learning, and put this new learning into action, *within* their current thinking operational level. This chapter provides an in-depth look into the educational framework proposed, and then shows examples of how it is used in the development of experimental activities. Educators following this advice will greatly enhance the educational outcomes of the experimental activities conducted.

Keywords: personalized learning, differentiation framework, Bloom's taxonomy, Piagetian and post-formal thinking, experiential learning

1. Introduction

There is no lack of pedagogical theories aimed at the K-12 education sector, many of which can be utilized together in order to provide an excellent education for children. Some of these theories are being employed in lower classmen with higher education to improve the educational outcomes of young adult learners [1–5]. Malcolm Knowles [6] popularized the term

IntechOpen

© 2018 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. CC BY

"andragogy," which refers to adult learning theories. These ideas became widespread in the 1960s, and typically referred to informal education for later year adults, who could draw on their life experiences as part of their learning. Formal education such as that experienced at university, community college or trade school, did not adopt such principles. These young adult learners can benefit from teaching and learning methods used in the high schools, but with extensions or adaptations to meet their undergraduate needs. Many have typically not gained sufficient "life experience" to benefit from andragogical teaching methodology as defined, and hence fall into an "in-between" educational group, where teaching methods need to be developed more formally.

This chapter outlines some key adaptations of pedagogical methods suitable in post-secondary education, followed by applications of these methods in chemical engineering undergraduate laboratory classes. It is anticipated that these methods would be useful for all Science, Technology, Engineering, and Mathematics (STEM) undergraduate and graduate education.

2. Development of an educational framework for STEM education

2.1. Piagetian and post-Piagetian (pP) learning theories

Piaget's theory, or Piagetian theory, has had a huge impact on the educational beliefs of educators around the world, and has largely dictated the "expected" intellectual development of children as they progress from birth to adulthood [7]. While this theory is still well accepted in many educational domains, the connections with biological progression of childhood development have come under scrutiny. It is well documented that students acquire new knowledge in a series of progressive stages (matching Piagetian stages), except that this development occurs at vastly different rates between students, with factors such as level of maturity, experience, culture, and individual ability strongly influencing these rates [8]. Due to these different rates of progression, it has been well observed that as many as 50% of freshmen students in higher education have yet to complete the final stage of Piagetian acquirement of knowledge [7].

Briefly, the four stages outlined by Piaget are (a) the sensorimotor stage for infants (0–2 years); (b) the pre-operational stage (2–7 years); (c) the concrete operational stage (7–11 years); and (d) the formal operational stage (12–15 years) [7–9]. The sensorimotor stage sees infants acquiring knowledge using their sensory skills such as touch, sight, or feelings, and is present with the infant right up until the time speech begins. The pre-operational stage occurs when young children use the additional skill of language to bring further meaning to their knowledge development. While language is used to describe various situations, there is often an over-exaggeration and little logic to the verbal explanations, and others opinions have little impact on the learner, although they may be copied. At the concrete operational stage, children are able to expand their thought processes and overall intellect by incorporating logic, comparing objects, and understanding concrete ideas [8]. In the final stage of Piaget's theory, the learner can deal with more abstract ideas, construct their own thought patterns, and evaluate information provided;

however, while they can evaluate and make sense of information, typically only one single answer will be considered "correct" [8, 10].

More recently, Piagetian theory has been extended to include further thought patterns, commonly known as post-Piagetian (pP) or post-formal ideas. In a study by Wu and Chiou [10], post-formal thinking was linked to creativity, and also the need for creativity in science (and likely STEM) fields to pursue and generate original thought. Although formal operational thinking is required for performing systematic tasks—a necessity in STEM fields—it does not allow for creativity, as formal thinkers believe there is only one correct answer [10]. Therefore, successful STEM researchers need to display both formal and creative thinking. Post-formal or pP levels of development are said to include two further stages: (e) relativistic thinking; and (f) dialectical thinking. In relativistic thinking, the learner begins to observe contradictions with potential solutions, and ultimately accepts that more than one solution is plausible given different ways of viewing a particular situation. This acceptance of other perspectives enables more novel solutions to ultimately be found. In dialectical thinking, the learner is open to new knowledge, and in fact *expects* to change their current thought pattern as new knowledge is found or presented. This is known as an "evolution of knowledge" thought pattern, and essentially can only evolve *from* contradictions of thought. Dialectical thinking enables the learner to synthesize new thought, and is essential for the creative process. Researchers operating at this level are typically more creative [10]. A final stage in thinking skill suggested here is (g) creative or independent thinking, where post-formal thinking has become an independent process, and the learner no longer relies upon guidance to come up with individual thought. This helps distinguish the educator demonstrating and encouraging development of thinking patterns (e) and (f) to research students versus those who have since mastered the "art" of thinking. The ultimate goal of a successful PhD student is one who is equipped with sufficient thinking intellect to be independent, and hence thinking stage (g) is included in the current discussion. These last three stages can equally be applied to professionals in their respective fields who have gained expert-level competence and independence of thought.

Given seven progressive stages of thinking skill development and acquirement, influenced by many outside factors influencing the rate of development, a typical class will consist of students operating at varying thinking levels. As such, it is important to run all classes, even in higher education settings, in a differentiated fashion to meet the needs of all students.

2.2. Differentiated or personalized learning theories

Carol Tomlinson has made the differentiated teaching and learning pedagogy famous, particularly in the K-12 educational sector [11–13], also more recently known as personalized learning. The ultimate goals of differentiated teaching is to promote growth in learning of *all* students from their starting point, ultimately promoting independence of learning within their particular stage of intellectual thinking development. With the explosion of the computer age, many automated tools are being developed to provide drill practice for students at their level of competency, gradually increasing or decreasing the level of difficulty as required. This is one of many tools at an educator's disposal to utilize in the classroom. Others include providing

differentiated homework sheets; group work to conduct more open-ended problems; inquiry-based learning tasks; experiential learning tasks; active learning; and many more. Each of these tasks, if carefully constructed, provides opportunities for learners to actively engage with the material, promoting depth of learning within their zone of proximal development (ZPD) [14], all the while challenging them to the next level of thinking.

This method of teaching (and learning) is quite popular at the K-12 level, despite some inevitable critics [15]. However, it is yet to gain popularity and commonality in higher and graduate level education. Much of this is to do with the fact that the original Piagetian theory concluded formal operational thinking by age 15, and hence there was no need for differentiated learning in higher education settings, since *all* students would be performing at the same intellectual level of thinking. More recent post-formal thinking levels, and an acceptance of different rates of thinking development in all learners, strongly dictate the necessity to continue differentiated learning into the higher education sector.

2.2.1. Differentiated learning in K-12 education

Differentiated learning is described by a number of key characteristics by several researchers in the field [16–23], and these have been further summarized into five key differentiation principles, DP1–DP5 below [24]:

1. Understand student need and preferred learning modes.
2. Focus on key concepts and provide multiple approaches to learning.
3. Provide challenging learning experiences within each student's ZPD.
4. Foster collaboration between students and their faculty.
5. Create independent learners and ownership of learning.

For concrete operational thinkers, the educator would likely recap prior core knowledge before beginning a new topic, and identify the types of activities that students prefer to assist their learning (DP1). When teaching the key concepts of the topic, the educator would incorporate variety in the activities, but would provide strong guidance and instructional teaching regardless of activity being undertaken (DP2). Problem-solving and critical thinking would be explicitly demonstrated to the students to enable them to follow similar patterns when solving problems on their own (DP3). Group activities would feature strongly in the learning, however in the early stages, students would learn "how to work in groups" more so than relying specifically on group tasks to promote further learning (DP4). Finally, the educator would provide tasks that competent learners within this thinking category could successfully complete unaided, but the vast majority of tasks would be those following pre-specified steps.

By contrast, for formal operational thinkers, the educator would create opportunities for learners to be more responsible for their own learning. For example, while he/she would still identify the existing knowledge of the learners, review of the core knowledge would be up to the student (DP1) and, although the key concepts would still be taught in multiple ways,

there would be less dependence on the instructional approach, providing more freedom for students to explore abstract problems (DP2). Challenging tasks would rely on students' prior mastery of problem-solving skills, concentrating more on developing adaptations of these skills to non-routine problems (DP3). Collaborative tasks with other students would see the students now begin to rely on each other to add to existing knowledge, having now mastered the key functioning of a team (DP4). Independence would be demonstrated when learners rely on their own problem-solving skills, and those of their peers, to independently work problems and make sense of more abstract ones as well (DP5).

A detailed study by Valiandes [22] was conducted in 13 Cypriot primary schools, covering 479 fourth-grade students (average age 9 years) and 24 teachers. The students were functional at the pre-operational and concrete operational thinking stages of Piaget. An important aspect of this study was the in-depth support given to the teachers to adequately train them in differentiated teaching strategies. Students were tested on literacy skills, and post-test results were significantly better for students participating in differentiated learning than the control group, which had largely instructional-based learning. Typical observations of differentiated instruction included noting the time spent by the teacher (a) commenting on student general behavior; (b) providing additional examples; (c) direct teaching/asking questions; and (d) providing student guidelines for work. Other observations included identifying the degree of activity variation; providing personalized support to students; providing learning opportunities to students of all readiness levels; time for students to reflect on basic knowledge and skills, or prerequisite knowledge; prioritizing order of activities; accomplishing lesson objectives; and providing differentiated homework. Many of these observations fit well into the DP in the concrete operational level. As a result of this in-depth study, differentiated practices were described as [22]:

> *"instruction planning based on constructivism learning theory, the hierarchical order of learning activities (DP1), the maximization of students' active participation in the learning process, the reduction of teachers' talking time during teaching (DP2), the variation of activities, the opportunity for students to work at their own pace, the personalized support that students receive (DP3), the differentiation of activities according to students' interests and learning profile (DP4), and the continuous evaluation of students' achievement with a simultaneous and ongoing evaluation of the effectiveness of the learning process (DP5)."*

The above quote has been interlaced with the identification of the five DPs as explained earlier, to demonstrate that these principles broadly cover many descriptions of differentiated practices. This example shows both the effectiveness of differentiated instruction at (mostly) the concrete operational level, as well as the importance of fully equipping teachers with the appropriate skills in delivering such instruction.

2.2.2. Differentiated learning in higher education

Educators of lower classmen in the higher education sector may encounter significant numbers of students operating in the concrete or formal operational levels, and hence differentiating the instruction would follow a similar pattern to those outlined above in Section 2.2.1. This is adequately demonstrated by a few reported studies of freshmen level mathematics

classes [25, 26]. In the study by Chamberlin and Powers [25], freshmen mathematics students taking "number and operations" were studied. Data were initially gathered on the students to judge their interests and preferred learning modes (DP1). Graduated activities were then implemented, each aimed at differing levels of intellectual readiness based on an analysis of the students' pre-requisite core knowledge. These activities included class extension activities, student work groups, student choice in activities, direct instructional modification as required, differentiated homework sheets, and formative/summative testing (DP2–DP4). Analysis of the pre- and post-testing indicated that students receiving differentiated instruction improved by 1.7 points out of 8, while the control group improved by only 0.3 points. It was concluded that the differentiated learning was successful, and mastery of required skills and independence in performance was observed (DP5) at the thinking operational levels of the students. The range of activities particularly identifies students working in the concrete and formal operation stages.

What might a differentiated classroom look like for upper classmen, or learners intellectually ready to undertake relativistic and/or dialectical thinking? In these two stages, the learner would gradually take on a more active role in their learning skill development through the five DPs. While these principles remain similar, the learner would become more active in participating and directing the learning, with the educator playing a guidance role. In relativistic thinking stages, the educator may still outline the required pre-requisite knowledge but would expect the student to revise accordingly. The educator would still deliver key concepts in multiple ways, but the learner would also be expected to experiment with different modes of learning, in order to maximize knowledge retention. In DP3–DP4, the activities presented to the students would begin at lower level (concrete thinking) to confirm knowledge of new concepts, but would progress to include abstract and ill-defined problems that present different solution paths.

In the dialectical thinking stage, the learner would take an even more active role in understanding his/her needs at the beginning of a new topic, and deciphering the key concepts of that topic. This level of learning/instruction within a formal institution would be seen in graduate level classes, advanced students in lower level classes, or research studies. As such, the activities in DP3 and DP4 would be learner-initiated (possibly at the initial direction of the educator), where learners would delve in depth into the chosen topic and make sense of the apparent contradictions presented. Students may eventually come to the realization of new knowledge as a result of these apparent anomalies.

In the final creative thinking stage, the learner has essentially mastered all previous stages of intellectual thinking development and can pursue a new field of interest at depth, and with the ability to creatively synthesize new knowledge. This would typically be seen with an advanced PhD student and/or experienced researchers, as well as expert industry professionals.

The extension of differentiated teaching and learning to the later stages of post-formal thinking is graphically displayed in Appendix A. The horizontal axis describes a progression in *differentiated learning skills* (DP1–DP5), while the vertical axis describes a progression in *thinking skills* (Piagetian and pP thinking stages). This arrangement shows the differentiation

http://dx.doi.org/10.5772/intechopen.75646

framework as it commonly stands in K-12 education (concrete and formal operations only), and then extended for later-year learners (post-formal thinking). Note that sensorimotor and pre-operational levels have been left blank, given that the focus is on higher educational training. Next to DP5 for each thinking level is a description of characteristics a learner will display once they have achieved independence with learning *at that thinking level*. This figure is to be interpreted as a continuum for both thinking and learning skills, and the characteristics described will alert the educator that the learner is ready to progress to the next level of intellectual thinking. The ages and approximate school year levels next to Piagetian and pP thinking stages are intended as a guide only, and are *very fluid*, with a particular reminder of the many outside influences that affect the rate of progression through these stages. This is true also for progressing through the various learning stages within each thinking level. Finally, the vertical axis to the right of the figure *loosely* assigns the different levels of Bloom's taxonomy, which also covers different thinking stages from lower to higher order thinking.

To the best of the author's knowledge, Appendix A is believed to be the first attempt by linking intellectual thinking skills at the higher and graduate education levels with a differentiation framework. Extensions to this level have not typically been considered to this depth. Several school systems provide differentiated curricula in all mainstream classes to grade 10, and then assume a more "one-size-fits-all" approach beyond this level (e.g., [27]). This is despite the general acceptance that Piagetian rates of progression are fluid, and competence in formal operational thinking by age 16 is no longer expected in *all* students. Hence, Appendix A is an attempt to provide additional differentiation assistance from grade 10.

2.3. Bloom's taxonomy

Bloom's taxonomy was originally published in 1956, and later developed and modified in 2002 by Krathwohl [28]. This most common form of Bloom's taxonomy is the cognitive domain, represented by lower order thinking (LOT) and higher order thinking (HOT) activities. However, two other domains have also been developed, which include the affective domain (interests, attitudes, and values) and the psychomotor domain (motor skills).

The cognitive domain can be used in a number of ways by the educator, and indeed learners, to fully master a topic of interest. In Appendix A, it can be seen that the six main cognitive stages of Bloom's taxonomy (LOT: remember, understand, and apply; and HOT: analyze, evaluate, and create) are loosely matched with the Piagetian and pP developmental thinking skills. In this way, the broad matching of categories indicates that it takes many years to move through the LOT and HOT cognitive domains suggested by Bloom, showing that progressive intellectual development is required to access higher levels of Bloom's taxonomy. This taxonomy is progressive in a similar manner as Piagetian thinking skills, and demonstrates that one must be comfortable with LOT before accessing HOT.

On a much smaller scale, an educator may commonly use this taxonomy for a particular topic or even a single class being presented to learners. Tasks will be organized such that early activities require students to remember and understand new terminology and concepts, and later ones will provide opportunity in applying these concepts to progressively more difficult

tasks. The depth of LOT and HOT will vary depending on the intellectual thinking level of the learner (Piagetian and pP), and hence the ability to "create" new knowledge for any given topic will be limited by the depth of thinking capability of the learner.

Fully independent learners operating in the creative domain of post-formal thinking will have developed their own methods of learning a new topic to expert level, based on a culmination of all previous learning they have experienced to that point. Even at this fully independent thinking stage, a learner to a new topic of interest will still need to progress through LOT and HOT in order to become sufficiently competent in a new field. These learners will have the skills to generate *actual* new knowledge, as opposed to learners operating at lower thinking skill levels, who will create new knowledge *for them* in their overall development. This is a key difference between a researcher or industry expert generating new knowledge and a learner becoming competent in their field.

The five broad DP also to some degree have links with Bloom's LOT and HOT. For example, in DP1 and DP2, the teaching and learning focus is on understanding existing knowledge and learning concepts of a new topic. In DP3 and DP4, the focus shifts to applying this newly gained knowledge to progressively more difficult tasks, which require some degree of the analysis and evaluation of the assigned problem. Finally, in DP5, independence of the learner within their current thinking skill category is reached when they are able to become fully competent with the range of tasks required, creating new knowledge *for them*.

To recap, Bloom's taxonomy can be used as a tool to (a) demonstrate life-long learning; (b) frame the teaching of a given topic; and (c) frame the learning of a given topic for more independent learners.

3. Developing experimental activities within the educational framework for chemical engineering

Within the framework, previously discussed are many opportunities for the educator to develop and deliver a variety of learning activities. While there are many activities available in an educator's "toolkit" for various situations, only experiential learning will be explored here, which governs the nature of experimental tasks and other experience-based non-experimental learning activities for the class. This learning theory, together with the educational framework discussed, will be demonstrated in the development of experiential activities for chemical engineering undergraduates.

3.1. Experiential learning theory

Kolb's experiential learning was progressed to its current form from significant earlier works of Dewey, Lewin, and Piaget [29]. Its prime motivation is the acquirement of knowledge through experience. The four modes of learning are (a) concrete experience; (b) reflective observation; (c) abstract conceptualization or thinking; and (d) active experimentation, or acting on one's new knowledge [29]. These are often summarized into: experience; reflect; think;

and act. This curiosity-driven learning increases engagement and interest of students, helping them to achieve learning independence. Similarities can be observed with the Piagetian and pP thinking stages, where the earlier ones are concerned with experience (touch, visual, smell, etc.); the intermediate stages develop reflection and thinking about observations; and the final stages promote action of a learner to discover new information for her/himself.

As an activity in an educator's toolkit, this theory can be shown as a small in-class thinking task to explain an observation; as a longer-term real-life assignment or design project; or as a formal experimental class. Such activities could form the instruction over DP2–DP4, depending on depth and time constraints. To avoid confusion, an *experimental class* is a subset of *experiential learning*, and not all experiential activities need to include experiments.

3.2. Developing an experimental activity in chemical engineering

Following the differentiation framework and interactions with Piagetian and pP theories, as well as Bloom's taxonomy, the educator must start at DP1 by "knowing the student needs." Knowing these needs will determine which Piagetian thinking skills primarily make up the laboratory class. For lower classmen, the students would typically be operating over a range of concrete, formal, and relativistic, while for upper classmen, the latter two would be more common, perhaps with some operating at dialectical thinking stage. However, each class is unique, and this must be determined by the educators running the theory classes, and discussed with the educators running the practical classes (as is most usually the case).

Having decided on two or three thinking skill levels that best represent the class, the educator will then develop the practical class on a particular unit operation with key learning objectives in mind, mostly within the DP2–DP4 range. Within this range, the level of difficulty of the tasks increases, from providing conceptual knowledge of the experiment through to applying this knowledge, and then analyzing and evaluating the resulting data. This is akin to the middle part of a Bloom's taxonomy cycle. DP5, where students practice independence, may be incorporated by a final task that requires the students to come up with a part or all of an extended investigation from their experimental task. This will build on their knowledge gained within the previous DPs, and will equip them with independent skills *within* their thinking skill range. When developing the experimental class, the educator should also keep in mind the experiential learning cycle just described, allowing adequate opportunity for reflection and cognitive thinking after an observation, followed by tasks that allow the students to actively use their newly gained knowledge.

A common method to incorporate different levels of thinking operational ability is to include choice between the required tasks. Those operating at higher thinking levels will typically choose the tasks that satisfy their need and hunger for learning, while those at lower levels will choose tasks more suitable for them. Rarely do students choose "the easy way out," as discovered by Hutton-Prager and O'Haver [30], and the vast majority of students genuinely engage with material by challenging themselves.

A planning template is shown in **Table 1**, demonstrating how the educational framework and pedagogies can be used to develop a meaningful laboratory class. The final format to the

DP	Theories	Description
1	Differentiation framework	The educator must first determine the key learning objectives for the laboratory class, including the "bare minimum" acceptable levels of knowledge to be gained. She/he then considers the prior knowledge of the students coming into the laboratory class. What thinking level (Piagetian, pP) are the students operating at? The educator confers with other professors who know the students well.
2	Differentiation framework; LOT from Bloom's taxonomy	A short and concise theoretical base of the unit operation intended for the experimental study is provided, including references to more detailed discussions. This will assist students learning this for the first time and those who need a brief review.
3–4	Differentiation framework; LOT from Bloom's taxonomy	As most laboratory classes are done in groups, DP3 and DP4 will be considered together. Regardless of thinking operational level within the class, it is good to begin with some concrete tasks to confirm one's knowledge, and become competent in operating the equipment. A precise procedure* on how to routinely operate the equipment is provided.
	Progressively challenging tasks covering Piagetian and pP thinking levels; "experience" and "reflect" from experiential learning	A variety of tasks are designed for the students to collect data/observations for subsequent analysis, and the precise instructions are gradually reduced as the students gain competence running the unit operation. These data collection tasks need to align with the key learning objectives, and will allow students to fully explore the capabilities or function of the unit operation.
	HOT from Bloom's taxonomy; "reflect" and "think" from experiential learning	Utilizing the collected data, written response tasks are provided that require students to analyze and evaluate the information, drawing on their knowledge and the theory behind the unit operation. Many of these tasks are open-ended to ensure reflection/in-depth thinking by the students.
5	HOT from Bloom's taxonomy; "act" from experiential learning	Within the ability levels of the learners, an extension to the investigation is provided, where the students are required to come up with their own procedure to investigate a new phenomenon on the unit operation. An applied response task to this investigation is also included.

*Precise procedure required for safety reasons; use DP5 to allow students freedom in coming up with a new experimental task instead.

Table 1. Planning template to assist in coming up with a well-rounded experimental task, meeting all the required learning objectives.

students would be a handout (or part of an experimental booklet) detailing the unit operation name, theory, tasks, and questions. Report write-up differs between colleges, and specific information on how this is to be done needs to be conveyed to the students. It is common to follow the format of a typical research publication.

3.2.1. Dissecting unit operation experimental activities into educational outcomes

There are some dedicated educational researchers looking into developing meaningful experimental activities that promote long-term retention and learning by the students (for example,

see [31–34]). Frequently, experiments are labeled as "cookbook" experiments, where students follow a detailed set of instructions and describe what they observe [33]. While this does have obvious advantages from a safety and time viewpoint, on its own, it does not provide sufficient opportunity for students to practice HOT questions and reflective activities as per experiential learning principles. However, as a differentiated activity, some students may *require* a more "cookbook" style experiment to assist progression of their learning, but this would still be incorporated with other opportunities to extend thinking. It is important to take into account the students' thinking levels when developing experimental tasks.

Some more "innovative" experiments presented at the American Society of Engineering Education (ASEE) annual conference in 2016, have been reviewed as per the template described in **Table 1**, and their results appear in **Table 2**. The reader is encouraged to read the full publications, as only a brief summary is presented here. This summary is based only on the conference presentation materials, and not the actual laboratory information presented to the students.

DP	Theories	Experiment 1: Mechanical properties of foods [34]	Experiment 2: Unsteady state conduction [34]	Experiment 3: Air conditioner experiment—thermodynamics cycle [32]
1	Differentiation framework	Detailed objectives provided	Detailed objectives provided	Does not appear to have been provided.
2	Differentiation framework; LOT from Bloom's taxonomy	Fundamental physical properties of food in unit operations covered in classes preceding experimental activity.	Fourier's Law of conduction previously developed in classes.	Pre-lab worksheet completed with instructor guided demonstration of equipment, discussing equipment, concepts and how to collect data.
3–4	Differentiation framework; LOT from Bloom's taxonomy.	Operating procedure provided	Operating procedure provided	No procedures provided, in lieu of the previous week's demonstration of the equipment.
	Progressively challenging tasks; "experience" and "reflect" from experiential learning	Experiment was designed in three parts, progressively becoming more difficult.	Difficult to assess—does not appear to progress tasks.	Spreadsheet assignment done individually, asking for specific calculations and tables to be created in Excel.
	HOT from Bloom's taxonomy; "reflect" and "think" from experiential learning	Good assessment questions which are open-ended and require students to think and reflect.	Assessment tasks require calculations but they do not appear to provide depth beyond calculation procedures.	Target audience given to each group. Team devised experimental plan based on their audience, and collected relevant data.
5	HOT from Bloom's taxonomy; "act" from experiential learning	None provided, but difficult to determine from information provided.	None provided.	A3 lab report poster required for submission; website creation to explain new concepts learned.

Table 2. Summary of three experimental tasks, dissected into the proposed framework.

This small sample of experiments demonstrates many of the tasks required as per the planning template (**Table 1**). Two of the three experimental tasks provided detailed objectives. It could not be determined from the information provided whether or not student ability or operational thinking levels were taken into account. Based on the description of tasks performed, Experiment 1 would suit formal operational thinkers; Experiment 2 would be better suited for concrete—formal operational thinkers; and Experiment 3 would be an excellent task for formal—relativistic thinkers. The first two experiments lack the creativity and HOT tasks (even at the suitable thinking levels), while the third experiment lacks some initial tasks at the LOT level to assist students in building their knowledge. The pre-laboratory worksheet and Excel task may be sufficient, but this will depend on the operational thinking levels of the students performing this task. The creative tasks discussed in Experiment 3 were pleasing to see, and fully met the requirements of HOT and experiential learning in a fun and engaging way for the students.

These same experiments could be written for students performing at different thinking skill development levels, and activities within each of the learning skill (DP) categories would hence vary to accommodate the different thinking levels. If Experiment 2 was used at the concrete operational development level, DP3–DP4 would need to be populated with additional experimental tasks and at least one open-ended question. There would also need to be a task included in which students could "act" on their new knowledge and participate in HOT at their operational thinking level. If this same experiment was developed for formal and/or relativistic thinkers, then there would be more challenging activities included within DP3–DP4 exploring different aspects of Fourier's law; many more open-ended questions; and full exploratory tasks with no direction provided by the instructor. However, this would need to be preceded by some concrete activities to prepare the students in competency of equipment operation, both from a safety viewpoint as well as providing groundwork in which they can build knowledge. This was well-demonstrated in Experiment 3.

By stark contrast, the more common "cookbook" experiments [33] would typically provide objectives (DP1); sometimes a background theory (DP2); a step-by-step procedure to be followed *exactly*; a set of basic analysis and closed questions relating to the observations (partial requirement of DP3–DP4); and no extended task from the learning gained (no DP5). This setup lacks student engagement and does not extend the theoretical learning provided in class into practical settings [33].

3.2.2. Example of a freshman design project developed within the educational framework

Hutton-Prager has previously described a Freshman design project implemented in ChE101: Introduction to Chemical Engineering at the University of Mississippi (UM) [30, 35], as part of the development of differentiated teaching and learning. Each semester, this four-week program requires students to investigate the full-scale processing of a candy bar. It begins with student groups making the candy bar in a food laboratory, and observing the intricacies required to successfully prepare the bar. Data and observations are collected and subsequently analyzed, along with a detailed investigation of the scale-up process. **Table 3** demonstrates how this project meets the requirements of the experimental planning template (**Table 1**), covering all aspects of DP1–DP5, Bloom's taxonomy and experiential learning.

DP	Theories	Description
1	Differentiation framework	The educator, having spent most of the semester with the students, has determined that most students are operating in the concrete and formal operations stages. The key objectives of the freshman design project are: • Provide a real-life example from the food industry where chemical engineers may be employed. • Understand the process conditions required for control in a full-scale process. • Perform calculations of flow rate, pressure, and temperature. • Identify unit operations within the candy-bar process. • Gain an appreciation of what is required for scale-up of a "recipe" to bulk production of candy bars. • Learn how to draw flow charts of the process. • Consider economic aspects of the candy-bar process.
2	Differentiation framework; LOT from Bloom's taxonomy	The project statement provided to the students details a real-life scenario of a student on an internship, involved in doing some plant trials to scale-up a new candy bar for potential sale. All the learning leading up to this design project is on developing skill in conducting pressure, temperature, and flow rate calculations.
3–4	Differentiation framework; LOT from Bloom's taxonomy	A recipe is provided to the students that carefully details the exact steps to be taken to make a small-scale version of the candy bar (likened to a plant trial in the scenario). Discussions before the practical session require students to think about how they will log their temperature vs. time data in the various sections of the candy-bar preparation, and come up with their own observation sheets.
	Progressively challenging tasks covering Piagetian and pP thinking levels; "experience" and "reflect" from experiential learning	Students are encouraged to come up with their own methods for the chocolate coating of the candy bar. They are advised before the experimental trial to research into the most suitable methods for chocolate coating. During the laboratory class, students identify different unit operations and think about how these stages would need to be modified if being prepared on a much larger scale. As an example, they quickly realize that manually stirring the mixture over a hot plate will require substantial modifications on a large scale.
	HOT from Bloom's taxonomy; "reflect" and "think" from experiential learning	In the subsequent weeks after the experimental session, students work their way through a guided template report, in which they are required to graph their temperature vs. time data; perform statistical calculations on the data; explain their observations; and explain the chemistry behind the candy-bar process. The choice of candy bar *always* involves a caramelization step or a bicarbonate soda reaction step, which requires thinking/reflection by the students to scientifically explain the observations from the experimental trial. This is framed by an executive summary; background on the candy-bar company; conclusions; and recommendations on whether to go to full-scale production. The *actual* answer is irrelevant; it is the analysis/evaluation of the trial in coming to a recommendation that is important.
5	HOT from Bloom's taxonomy; "act" from experiential learning	Students are asked to explore scale-up of their process. They identify the unit operations of the process; decide on an order for continuous candy bar preparation; draw a block-flow diagram representing the full-scale process; choose a unit operation to explore its detailed design; perform example calculations of flow rate, average molecular weight, etc.; and consider some economic impacts on the final sale of the candy bar. They submit their written report with a "supervisor" target audience, and produce a 5-min verbal presentation discussing their experimental trial, the results, and their recommendations.

Table 3. Description of the freshman design project implemented in ChE101: Introduction to Chemical Engineering, at University of Mississippi.

This design project covers all four stages of experiential learning (experience, reflect, think, and act); the five differentiation principles; and both LOT and HOT from Bloom's taxonomy. Bare minimums have been built into the written report, where students must demonstrate their skill in the required calculations and explanations of observations. In DP5 where students explore the scale-up process, they have a choice in which unit operation to investigate. Depending on operational thinking level, students may choose an "easier" unit operation that requires less explanation than others, and will not be penalized. There is no upper limit to the depth in which students explore this project. The final requirement of the verbal presentation provides opportunities for students to learn oral communication skills, and importantly promotes independence as they explain their project in a realistic scenario.

4. Non-experimental experiential activities

It is worth completing this discussion with a brief explanation of experiential activities that can be performed in a theory class. Remembering that experiential learning requires reflecting, thinking, and acting after an experience, a common activity employed by an educator is a thinking experiment. This requires the students to imagine a particular unit operation, and think about how it might work. Others might include practical demonstrations, real-life scenarios, or "story-telling" particularly in the form of analogies, which enables the learners to access the complexities of a topic using more familiar situations.

The author has previously introduced a very successful thinking experiment into ChE417: Separation Processes, at UM on fixed bed adsorbers. This is preceded by a theory lesson outlining the basic terminology of adsorption processes, typical adsorbents, and applications, followed by the various adsorption isotherms commonly discussed in the literature. This helps to build knowledge and creates an "experience" (although theoretical) of how adsorbers work and their typical applications. The thinking experiment begins in the following class, where the students are asked to think about how the concentration of solute in the fluid would vary as it travels over the length of a fixed bed adsorber. They draw their thoughts on a concentration vs. length graph. This is followed by a class discussion on mass transfer zones, and then students are asked to think about whether a narrow or wide mass transfer zone is better, with justification. They then need to discuss in groups what types of factors might affect the length and the rate of movement of this mass transfer zone, and are challenged to come up with at least 10 different factors. The thinking experiment continues where students are asked to draw on a concentration vs. time graph what the breakthrough situation may look like. With further discussion, they come to the realization that integrating such a curve will represent the amount of solute adsorbed for a given time. This exercise is highly engaging for the students, and enables them to fully "experience" the workings of a fixed bed adsorber, with considerable reflection and cognitive developmental opportunities. Acting on this new knowledge is subsequently gained with calculation questions for fixed bed adsorber design.

http://dx.doi.org/10.5772/intechopen.75646

This straightforward example of presenting content in a highly engaging way demonstrates how a unit operations "experiment" can still be conducted effectively within a theory class. This type of teaching and learning is particularly suited to smaller colleges where equipment and funding may be minimal. Studies have shown that experiential learning activities such as the one described are only marginally less successful than an actual experimental program [36]. If the experimental programs are not carefully developed as outlined earlier in this chapter, then the net gain of experiential learning *via* experiment is reduced, and active learning activities within a theory class can be equally or more beneficial.

5. Conclusions

A differentiation framework for higher education has been introduced and discussed, which extends the framework commonly used in K-12 education systems. This framework has been built on existing ideas of post-Piagetian thinking levels, and has mapped each thinking level to five broad differentiation principles. The framework has also been linked to Bloom's taxonomy of lower and higher order thinking skills.

Using this differentiation framework and experiential learning theories, a model for experimental classes in undergraduate chemical engineering unit operations has been developed. This model has been demonstrated using some pre-existing experimental activities described at ASEE 2016 [32, 34]. Its full capacity has been shown with a freshman chemical engineering design project currently operational at the University of Mississippi, providing examples of how all aspects of a differentiated activity can be developed, meeting the requirements of both thinking and learning skill development.

Acknowledgements

This work has been developed at the University of Mississippi, and is not funded externally.

Conflict of interest

The author has no conflict of interest.

A. Appendix

A differentiation framework of learning skills, matched to operational thinking ability level, described by Piagetian and post-Piagetian theories.

PIAGET AND POST-PIAGET THINKING SKILLS AND DEVELOPMENT						
graduate education; education for life	22 years and above	Independent / Creative Thinker	When learners first encounter a new topic, they will revise any prior learning as required to progress with the new learning. They will identify and learn any new terminology, and fully understand what the terminiology means. As they progress through the depth of learning a new topic, they will frequently check their progress to ensure they are gaining and maintaining long-term knowledge.	Learners will identify key concepts required in the new topic, and set about understanding them using the mode of learning that suits them best. Given that they have an appreciation for several different modes of learning, they may choose a few different ones in order to assist with their knowledge development. They will likely have in mind, or discover, some key applications of the topic they are investigating.	Learners will expand their conceptual knowledge by going into depth on specific areas of interest within the broad topic. They will likely start with concrete problems to confirm their knowledge, and then progress through more abstract cases, developing opinions and conclusions based on the information they have sought. They will suggest detailed experimental / computational programs to test new theories and/or justify potential contradictions in the literature.
undergrad to graduate education	19 years and above	Dialectical Thinker	Learners will identify core pre-requisite knowledge of a new field of work, possibly in conjunction with an advisor / educator. They will be guided by the educator regarding how/where to find suitable information on their topic of interest, and the advisor will check in regularly to gauge the learner's development with the new content.	The learner and advisor will jointly decide on the key concepts required of the new topic, and the learner will employ his/her most favored learning modes in order to start developing detailed knowledge of the content area. They will familiarize themselves with likely applications to maintain interest.	Learners will study in depth specific areas of their chosen field as they expand their ZPD. They will begin with a concrete understanding of the facts, and progress through formal and relativistic problems. Contradictory information presented will force them to create new knowledge as they make sense of these differences. They will be able to carry out research programs, with some advisor guidance, and use new information to confirm different beliefs prevalent in the literature.
senior high school to upper classmen university	17 years and above	Relativistic Knowledge	The educator outlines prior core knowledge required for the course, and expects the students to revise this content if needed. Formative testing will be maintained throughout the course, and the educator will gain an understanding of preferred learning modes, but will also expect students to adapt to other modes of learning delivered. Students will be able to 'convert' any learning mode delivered into their preferred mode.	The educator identifies the key concepts of a topic, and determines 'bare minimum' acceptable competencies. The educator then chooses multiple ways of delivering the learning to promote engagement and interest. Students also experiment with these different methods of delivery and investigate their own in order to promote learning.	The educator provides challenging tasks for each student within their ZPD, while encouraging students to their next level of understanding. Activities include concrete, operational and relativistic tasks to progress skill development through different thinking levels. Relativistic tasks will involve abstract and ill-defined problems, requiring students to evaluate the material and make informed assumptions to successfully solve the problem.
middle school to lower classmen university	12-22 years	Formal Operations	The educator determines the entry-level ability of the students; what learning modes maximise their understanding; and what prior core knowledge is required. Regular formative testing throughout the semester informs the educator of academic progress and potential issues that require adressing.	The educator identifies the key concepts of a topic, and determines 'bare minimum' acceptable competencies. The educator then chooses multiple ways of delivering the learning in ways that match preferred learning modes. Repetition of the learning with different approaches will also enhance engagement, interest and relevence.	The educator develops critical thinking and problem-solving skills through carefully planned activities, which require students to think beyond standard solution methods in order to successfully solve problems. The educator provides tasks that expand the student's current ZPD. Concrete tasks will be assigned to familiarize the student with content, followed by more abstract problems to develop critical thinking.
primary to high school	7-18 years	Concrete Operations	The educator recaps prior core knowledge before starting a new topic, and conducts formative and summative testing throughout the semester. The educator will ask what types of activities the students prefer most, and include these in the curriculum.	The educator identifies key concepts of a topic, and determines 'bare minimum' acceptable competencies. Content is delivered several different ways to engage students and maintain interest; however, strong guidance will feature in all ways employed. Specific instructions will be included during 'lecturing', working problems, creating posters, etc. Experiential learning will be overlaced with specificity in task description.	The educator will introduce the methods of problem-solving and critical thinking to the students, with specific instructions on 'how to problem-solve'. To prepare the more advanced students for operational thinking, the educator can provide tasks that require deviations from the standard set of instructions.
kinder to low primary	2-7 years	Pre-operational stage			
pre-kinder	0 - 2 years	Sensorimotor stage			
			DP1	**DP2**	**DP3**
			Understand student needs and preferred learning modes	Focus on key concepts and provide multiple approaches to learning	Provide challenging learning experiences within each student's ZPD
			DIFFERENTIATED LEARNING SKILLS FRAMEWORK FOR THE EDUCATOR		
			Awareness of strengths / weaknesses; preferred mode of learning; and converting between modes	Identify key concepts and utilize several learning approaches to increase knowledge base	Challenge oneself with learning activities from lower to higher thinking skills to expand ZPD
			DIFFERENTIATED LEARNING SKILLS FRAMEWORK FOR THE STUDENT		

The learners will continue to expand their knowledge depth by seeking other expert opinions on their topic of interest, and attending events such as conferences or other scientific gatherings. They will gain further insight, and come to terms with apparent contradictions within their field of research.	Independent / creative thinkers will have acquired all necessary skills to become a life-long learner, and consequently an expert in their chosen field. They will employ, perhaps sub-consciously, a learning process they have become familiar with throughout their life, which progresses them through the different and learning stages to become fully independent. They will lead and develop new research programs in their chosen field of interest.	Self-motivated to learn; is an independent thinker and learner; uses experiences to form new belief patterns and knowledge in chosen field.	Create	BLOOM-S TAXONOMY OF LEARNING: LOWER AND HIGHER ORDER THINKING
Learners will have frequent discussions with their advisor regarding the apparent contradictions with their chosen field as they come to terms with the complexity of the field. They will also consult other peers and potential collaborators at universities to continue discussions, and likely join research forums. They will be able to analyze experimental / computational results from experiments with some guidance from the advisor to assist with their knowledge development.	Dielectical thinkers show independence when they become expert at the learning steps discussed (DP1-5). While they may require guidance from an advisor (eg PhD advisor) to get them to this stage, they will increasingly show more independence as time goes on. They will be able to contribute to research programs and assist in the direction of the research.	Sees evolution of knowledge resulting from contradictions within a thought system and outside factors. Willing to break from previously-held beliefs to consider new thoughts. Resolves apparent contradictions by means of higher order syntheses that create new, more complex systems that incorporate previous contradictory elements (52)	Evaluate	
The educator will provide lengthy, group projects that simulate a 'real-life' industry problem, such as the Capstone Design project in Engineering. Students will work closely with each other in their team and encounter multiple approaches of tackling a given problem. They will need to make educated decisions with justification as to why they have chosen a particular path of problem solving.	Relativistic thinkers take an active role in their learning. While the educator may still act as a facilitator, the students begin to rely more heavily on their own knowledge growth and those of their peers to make sense of ill-defined problems. They can justify different solution paths and explain why they result in different answers.	Encounters other opinions or approaches to problems that don't necessarily result in the same answer; accepts that more than one answer is possible; other perspectives assist in creative development (52)		
The educator provides group activities to promote social interaction between students and faculty, and importantly to enable students to learn from each other by developing trust. Various collaborative tasks ranging from small in-class activities to semester-long projects are designed to enable students to build skills in depending on others besides their educators for learning opportunities.	Formal operational thinkers build on the previous structure provided to 'learn how to learn'. The educator is viewed as a facilitator and guide more so than one who disseminates information. Students build up trust in themselves, fellow students and faculty, and develop their critical thinking and problem-solving skills to an extent where they can rely on these skills to approach any new topic, with confidence that they will be able to learn the content.	Reason with concepts, relationships, abstract properties, axioms and theories; uses symbols to express ideas; applies combinatorial, classification, conservation, serial ordering and proportional reasoning in abstract modes of thought; plans lengthy procedures to attain overall goals (one correct answer); aware and critical of own reasoning and checks validity of conclusions (53)	Analyze	
The educator provides group activities to enable students to learn teamwork skills. Activities that promote dependence on team members and trust in other members will be developed. Typically, shorter activities such as in-class or short team assignments will be incorporated into the learning. The learning is centered on how to build a functioning team more so than learning content within a group.	Concrete operational thinkers will utilize previous structured learning to motivate themselves to successfully solve problems on their own that follow standard rules. Although they have participated in group work, they may not rely heavily on peer opinions, and will require the educator to point out any inconsistencies with their work.	Needs reference to familiar actions, objects and observable properties; uses classification, conservation, serial ordering; needs step-by-step instructions in a lengthy procedure; unaware of inconsistencies in own reasoning among various statements of contradictions with other known facts (53)	Apply	Understand
	Children will use newly developed language and pictures to explain their world. Not all explanations will be logical or accurate, and will often be over-exaggerated as they experiment with language. There will be little reliance on others' opinions. Memory will feature strongly in knowledge independence.	Uses words and images to explain concepts and ideas (125)	Remember	
	The infant will have developed firm ideas based on sensory inputs to help explain his/her world. The infant will rely on adults to provide new stimulation or events in which to explore in a sensory manner, in order to expand knowledge.	Uses senses and actions to explain concepts and ideas (125)		
DP4	**DP5**	Characteristics of someone who has achieved independent learning at each level of thinking skill development		
Foster collaboration between students and faculty	Create independent learners and student ownership of learning			
DIFFERENTIATED LEARNING SKILLS FRAMEWORK FOR THE EDUCATOR				
Seek out other students / educators / researchers to broaden knowledge	Internally motivate oneself to achieve; build on earlier stages of learning to achieve independence			
DIFFERENTIATED LEARNING SKILLS FRAMEWORK FOR THE STUDENT				

Author details

Brenda Hutton-Prager[1,2]*

*Address all correspondence to: bhprager@olemiss.edu

1 University of Mississippi, University, MS, USA

2 American Institute of Chemical Engineers (AIChE), American Coatings Association (ACA), American Chemistry Society (ACS), Australian College of Educators (ACE), Registered Teacher – Victoria Institute of Teaching (VIT), Australia

References

[1] Farrell S, Cavanagh E. Biodiesel production, characterization, and performance: A hands-on project for first-year students. Education for Chemical Engineers. Apr 2014;**9**(2): e21-e31

[2] Golter PB, Thiessen DB, Van Wie BJ. Adoption of a non-lecture pedagogy in chemical engineering: Insights gained from observing an adopter. Journal of STEM Education. 2012;**13**(5):52-61

[3] Gómez Puente SM, van Eijck M, Jochems W. Towards characterising design-based learning in engineering education: A review of the literature. European Journal of Engineering Education. 2011 May;**36**(2):137-149

[4] Han JH, Finkelstein A. Understanding the effects of professors' pedagogical development with clicker assessment and feedback technologies and the impact on students' engagement and learning in higher education. Computers in Education. Jul 2013;**65**:64-76

[5] Mantri A. Working towards a scalable model of problem-based learning instruction in undergraduate engineering education. European Journal of Engineering Education. May 4, 2014;**39**(3):282-299

[6] Smith MK. Malcolm Knowles, informal adult education, self-direction and andragogy. Encyclopedia of Informal Education [Internet]. 2002. Available from: www.infed.org/thinkers/et-knowl.htm

[7] Tomlinson-Keasey CA. Chapter 1: Piaget's theory and college teaching. In: Essays from and about the ADAPT Program. 1978:29. http://digitalcommons.unl.edu/adaptessays/29

[8] Ojose B. Applying Piaget's theory of cognitive development to mathematics instruction. Mathematical Education. 2008;**18**(1):26-30

[9] Lefmann T, Combs-Orme T. Early brain development for social work practice: Integrating neuroscience with Piaget's theory of cognitive development. Journal of Human Behavior in the Social Environment. Jul 2013;**23**(5):640-647

[10] Wu P-L, Chiou W-B. Postformal thinking and creativity among late adolescents: A post-Piagetian approach. Adolescence. 2008;**43**(170):237-251

[11] Wu EH. The path leading to differentiation: An interview with Carol Tomlinson. Journal of Advanced Academics. May 2013;**24**(2):125-133

[12] Tomlinson CA. The Differentiated Classroom: Responding to the Needs of all Learners. Alexandria, VA: Association for Supervision and Curriculum Development; 1999. 132 p

[13] Tomlinson CA. To the contrary: Differentiation does work. Education Week Spotlight on Differentiated Instruction. Jan 2016:16-17

[14] Murphy C, Scantlebury K, Milne C. Using Vygotsky's zone of proximal development to propose and test an explanatory model for conceptualising coteaching in preservice science teacher education. Asia-Pacific Journal of Teacher Education. Aug 8, 2015;**43**(4):281-295

[15] Delisle JR. Differentiation doesn't work. Education Week Spotlight on Differentiated Instruction. Jan 2016:15

[16] Bullock J. Differentiated instruction, one size does not fit all. Education Week Spotlight on Differentiated Instruction. Jan 2016:9-11

[17] Davis MR. District's ambitious effort fuels personalized learning. Education Week Spotlight on Differentiated Instruction. Jan 2016:12-15

[18] Herold B. Literacy gets a personalized makeover. Education Week Spotlight on Differentiated Instruction. Jan 2016:2-4

[19] Manning S, Stanford B, Reeves S. Valuing the advanced learner: Differentiating up. Clearing House: A Journal of Educational Strategies, Issues and Ideas May 24, 2010; **83**(4):145-149

[20] Rock ML, Gregg M, Ellis E, Gable RA. REACH: A framework for differentiating classroom instruction. Preventing School Failure: Alternative Education for Children and Youth. Jan 2008;**52**(2):31-47

[21] Sparks SD. Differentiated instruction: A primer. Education Week Spotlight on Differentiated Instruction. Jan 2016:7-8

[22] Valiandes S. Evaluating the impact of differentiated instruction on literacy and reading in mixed ability classrooms: Quality and equity dimensions of education effectiveness. Studies in Educational Evaluation. Jun 2015;**45**:17-26

[23] Watts-Taffe S, Barbara Laster BP, Broach L, Marinak B, McDonald Connor C, Walker-Dalhouse D. Differentiated instruction: Making informed teacher decisions. The Reading Teacher. Dec 2012;**66**(4):303-314

[24] Prager BH. An Analysis of the Current VCE mathematics Study Design and Comparison with other Equivalent Designs with respect to the Principles of Differentiation. Victoria, Australia: The University of Melbourne; 2013

[25] Chamberlin M, Powers R. The promise of differentiated instruction for enhancing the mathematical understandings of college students. Teaching Mathematics and Its Applications. Sep 1, 2010;**29**(3):113-139

[26] Konstantinou-Katzi P, Tsolaki E, Meletiou-Mavrotheris M, Koutselini M. Differentiation of teaching and learning mathematics: An action research study in tertiary education. International Journal of Mathematical Education in Science and Technology. Apr 15, 2013;**44**(3):332-349

[27] Victorian Curriculum and Assessment Authority. The Victorian Curriculum F-10 [Internet]. Victoria State Government; Available from: http://victoriancurriculum.vcaa.vic.edu.au/

[28] Krathwohl DR. A revision of Bloom's taxonomy: An overview. Theory Into Practice. 2002;**41**(4):212-218

[29] Kolb DA. Chapter 2: The process of experiential learning. In: Experiential Learning: Experience as the Source of Learning and Development. Englewood Cliffs, NJ: Prentice Hall; 1984. pp. 20-38

[30] Hutton-Prager BH, O'Haver J. Work in progress – Implementing a differentiation framework into freshman engineering classes. In: 8th Annual First Year Engineering Experience Conference. Columbus, Ohio. 2016. (Session T2D)

[31] Anderson LS, Ferri JK, Cramer AD. Flipped Laboratories in Chemical & Biomolecular Engineering. In: ASEE 123rd Annual Conference & Exposition. New Orleans, LA; 2016. (Paper ID#16947)

[32] Garrison LA, Garrison TJ. A Laboratory Structured to Encourage Thoughtful, Task-Based Experimentation. In: ASEE 123rd Annual Conference & Exposition. New Orleans, LA; 2016

[33] Habibi M, Fearing C, Muslu M. Pros and Cons of Laboratory Methods used in Engineering Education. In: ASEE 123rd Annual Conference & Exposition. New Orleans, LA; 2016. (Paper ID #15975)

[34] Piergiovanni PR, Jarboe JH. Experiments for A Unit Operations in Food Engineering Course. In: ASEE 123rd Annual Conference & Exposition. New Orleans, LA; 2016. (Paper ID #15686)

[35] Hutton-Prager B. Design of differentiated curricula in freshman chemical engineering courses. In: AIChE Annual Meeting, San Francisco, California, USA; 2016. (Paper ID #454066, Session 293f)

[36] Vigeant MA, Prince MJ, Nottis KEK, Koretsky M, Ekstedt T. Hands-on, Screens-on, and Brains-on Activities for Important Concepts in Heat Transfer. In: New Orleans, LA; 2016. (Paper ID #14724)