Personalized learning is one of the grand challenges for engineers in the 21st century (NAE Grand Challenges for Engineering, 2016) from a technological point of view. As an educational strategy, it is known as differentiated learning or targeted learning, and is essentially a framework within which student need is identified early into a course. Armed with this information, educators carefully choose activities that best meet the needs of their learners to enhance the outcomes of every student.

The framework at the K-12 level consists of five principles (Rock, Gregg, Ellis & Gable, 2008; Tomlinson, 1999; Prager, 2013):
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 Zone of Proximal Development (ZPD);
4. Foster collaboration between students, and
5. Create independent learners and student ownership of learning.

This framework is well-practiced throughout the world in many K-12 settings (e.g. Valliandes, 2015; Wu, 2013; Bullock, 2016), but is sadly lacking in most higher education settings.

Putting the Theory into Practice...
A Freshman ChE101 class was recently taught where the differentiation principles were implemented into the class. Particular strategies included:
• Collecting initial student data on preferred learning modes; initial knowledge skill on mathematics and science; and beliefs regarding ability in these two areas
• ‘Toolkit’ of teaching strategies to deliver conceptual knowledge in multiple ways, including short lectures, think-pair-share activities, class participation in problem-solving questions, small-group discussions, reviewing suitable YouTube clips, kahoot quizzes...
• Differentiated homework sheets, that is, homework activities split up into beginning, intermediate and advanced questions
• Collaborative group activities in the form of a small design project on Mars Bar processing
• Independent study on ethics in engineering

Results:

The box plots in Figure 1 show the class statistics for four progressive assessment tasks. Test 2 and the Mars Bar assignment were completed after all four technical topics had been taught, while Test 1 was completed after half of the technical content. The Mars Bar project was done in teams of four, and the box plot shows a smaller spread of data, given that group rather than individual grades were assigned. The box plots for Test 1 show a dramatic rise in median grade achieved by the students after they had participated in learning of two topics using two differentiated homework sheets. The spread of data between 1st and 3rd quartiles was also considerably smaller, indicating improvement of the lower students. The median score continued to rise for Test 2, and the spread of data between the 1st and 3rd quartiles was again smaller and also higher, indicating improved knowledge throughout the semester. Importantly, the lowest score also doubled from the initial data to Test 2.

In a memory study, brain activation patterns imaged with fMRI showed that adults used long-term memory retrieval to access prior learned knowledge, whereas short-term memory (or working memory) which accesses a different part of the brain was not activated during the tests. Repetition eight times began to show brain activation in the regions of long-term memory storage (Ischebeck, Zamarion, Egger, Schoke, & Delazer, 2007). In another study by Ceunis (2016), it was the procedural memory that needed to be developed, and while higher-order thinking activities assisted in its development, practice and reinforcement was paramount to fully engrain the longer-term memory. Neurologist and educator Willis (2007) explained that dendrites form and communicate with neurons as more skills, information and experience is gained. They also become thicker the more different and engaging ways a concept is learned by students. However, their size also decreases if this information is not regularly used or practiced. Building relationship and creating experience for learners with their learning also assists the brain in building multiple pathways to store information.

Figure 2 shows the distribution of question choice for each of the four homework sheets, with average class scores overlaid. In homework sheet 2 there was a dramatic drop in the intermediate questions attempted coupled by almost twice the amount of advanced questions. The overall grade reduced, however, and the resulting lack of confidence dramatically changed the choice of questions in the third homework sheet. With building confidence at increased scores, the final homework sheet saw a rise from 6 to 20% of questions being attempted in the advanced category, this time with an overall higher grade on average.

The Mars Bar design project enabled in-depth learning of continuous processes, teamwork and communication skills. Student responses to a feedback questionnaire included:
• 87% learned key aspects of writing a technical report
• 74% learned how to give a verbal presentation
• 70% had a much better idea of a chemical engineer's role
• 65% learned a lot about teamwork cooperation and compromise.