Attaining Analysis, Evaluation, and Creation Level of Learning via Online Questions in Polymer and Chemical Reaction Engineering Course

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***Abstract*—Students' learning is organized by Bloom's Taxonomy in six levels. The significance of high levels of learning is confirmed by publications which clearly pointed out a gap between factual information students learnt from lectures and their applying ability in flexible situations in future study or workplace. This problem is caused by current teaching mode excessively concerning memorization of individual concepts but neglecting training students' logical thinking between concepts.**

To address the issue, this paper proposes skills in making high-order learning questions for online use aiming at cultivation of students' logical analysis, evaluating situations and results, and ultimately the creative ability, which are illustrated by examples in polymer and chemical reaction engineering course. Beyond these, suggestions to prevent a question reducing its level after one or two exposures are provided so that educators can take advantage of all techniques to formulate questions towards the goal of helping students achieve high levels of learning.

***Index Terms*—Engineering, High level of learning, Online, Question**

I. INTRODUCTION

As a recognized theoretical basis, Bloom's Taxonomy is widely used in education, which divides study into 6 levels and points out that low-level learning is the foundation of high levels[1]. It is difficult to help students attain high-level learning by current test mode since knowledge and comprehension account for over 80 per cent of total questions showing in quizzes and tests[2], [3]; in other words, the focus of teachers is to excessively strengthen students' information recitation and basic comprehension without the concern of training their logical thinking and creative ability. This possibly results from two reasons: one is that educators believe that these abilities are not critical to be trained throughout studies, which could be disagreed by most people; the other is that although their importance is affirmed, how to actually train students remains an insurmountable problem-at present, there is a lack of an effective method to gradually cultivate students' analysis of issues, evaluating situations, and inventiveness. To attain these abilities, high-order learning questions for a hybrid course are proposed.

Compared to basic questions, these have advantages towards the goal of high levels of learning. First, they are capable of truly training high-level skills. Today's most baccalaureate-degree recipients have experienced so-called standard format of teaching and learning. During class, instructors are intended to present a huge amount of factual information. In assessment, students are encouraged to summarize what they have been told in lectures or simply recall an equation to plug given numbers for the result. By doing so, people confidently suppose that no matter who gets a high score in such a training mode having the ability to deal with flexible situations in future study or workplace. However, did students truly learn? It is found that the fact is far from expected. There is a sharp gap between the knowledge students are given and their ability to analyze various situations, evaluate their answers, and even create their own work. One cannot assume that as long as students possess low level of learning, they would naturally obtain high-level skills[2], [4]. Indeed, these skills require specialized training via ad hoc methods, like high order learning questions which are able to essentially prevent learners cheating themselves during study.

Second, In-depth understanding of concepts is a prerequisite for solving high-order questions that are no longer in the format of 'plug and play' by recalling a concept or replacing values in a formula. Instead, they ask students to analyze and evaluate the logic connections among given conditions, and even create logics for a new output. This process takes students longer time for better preparation of the exam and to figure the questions out in test, after which, they highly likely understand the knowledge deeply and apply it in a more flexible situation[5]. More importantly, their logical thinking has been greatly developed. This is much more meaningful than recalling a few fundamental concepts and the calculation through basic formulas. After all, the goal of higher education is to teach students how to solve problems which the computer cannot, rather than to compete with it in memory and computing power, for which the advantage lies certainly with the computer.

A hybrid course is in a mixing format of online material and traditional teaching approach including lectures, homework, and in-class written exam. The purpose is to combine their benefits. Quiz-based online material guides students to think and learn mainly from questions displayed on platforms, such as Canvas and Blackboard. Its characteristics enable:

- flexible time of preparation for both professors and students
- self-paced learning designed to be accomplished at learner's own speed
- reduced demands on physical classroom facilities
- just-in-time feedback for incorrect answers to provide students who express the desire for detailed explanations [6].
- ability to repeat redundancy questions for reinforcement of learning which forces students to frequently recall and better understand the links between current learning materials and the previous.
- question-guided learning process matches the needs for two sorts of students: the ones not able to fully grasp the content during class or missing previous knowledge from pre-requisites pertaining to this class will have extra time to go over optional learning material such as example problems posted online; otherwise, it is not necessary to go through this material again for those who are well prepared or with well-organized fundamentals. For instance, in chemical reaction engineering course, a student from Chemical Engineering may take 2 minutes to understand a quiz question and gets started to find a solution whereas a student from Chemistry or Physics probably struggles with the meaning of concepts mentioned in the question for more than 10 minutes. This could happen during a regular class. The desire for explanation of fundamentals by professors to students without strong background is essentially difficult to be balanced. 10 minutes are possibly not enough for students without solid background. However, it is quite a waste for others. This common issue can be avoided via question-guided learning process.
- convenient and quick assessment. The majority of institution professors are looking for the way to construct exams with the type of questions that can be easily graded. Such an efficient way meets their needs. Once a student completes a test, the platform immediately displays current score and sum all the previous up for the final evaluation.
- detailed documentation of progress and level of learning: (a) students are able to share and discuss previous questions by email for the purpose of improving studies; (b) some like to review previous questions for the next test; (c) ones have personal preference to have the hardcopy of documentation after taking the online test; (d) students get to know which level of learning they stay on since each quiz question is specifically designed for a certain level.
- increased opportunities for engagement with more hands-on experience like $Matlab$ questions which allows students to edit, modify, and create a programmable code to numerically deal with issues in science and engineering study with colleagues (Group quiz) or individually (Individual quiz). A group learning environment through Group quizzes allows colleagues from different majors (math, chemistry, physics etc.) to have a common goal to help and benefit from each other[7], [8].
- susceptibility to develop a broader database of resources with effortless maintenance for continuous improvement process. This also makes it easier for teachers between different regions to exchange teaching materials.

The unique advantages of traditional teaching approach highlight its indispensability:

- availability to give more complex and time-consuming high-order questions to cultivate students' independent thinking in depth and divergent thinking in width.
- accessibility to provide more-disciplined routine for students who are lack of self-regulation and self-motivation.
- proctoring of exams
- attainability to have more personal communications with the teacher and social interactions with classmates who are capable of helping and encouraging with each other.
- flexibility of format to meet the need of two kinds of students. Some are comfortable with computers and numbers while others getting depressed facing machines want more individuals around them to be socialized.
- Clarification of unclear instructions or questions in which educator could not only explain in more detail compared to the feedback given by the online platform, but also emphasize more key points and typical mistakes that new learners tend to make based on previous students.

This paper is going to focus on the ways of making high order learning questions for online use.

II. APPROACH AND EXAMPLE

In the past, each level of learning in Bloom's Taxonomy was summarized in a few key words shown in Table 1[9]–[12]. This ambiguous interpretation is likely to cause instructors' confusion leading to a difficulty to prepare a question for a target level. In fact, levels of learning can be seen from a logical perspective displayed in Figure 1. Low-level learning including Remembering, Understanding, and Application is mainly concerned about an individual concept defined as a term, a formula, or a principle. From Analysis level, it begins to enter a field of seeking logical links: high-level learning places great emphasis on the logical relationship between concepts.

Question preparation for three fundamental levels will not be discussed here for the following reasons. To begin with, it is recognized that high level of learning is built on low level(s). Accordingly, solving high order questions has already taken into account the investigation of memorization and understanding. Besides, questions at low levels are mostly about the interception of concepts, or to simply recall them.

To examine all correlated concepts, their proposition is not tough but quite time-consuming since each question emphasizes on a single one. In order to test all related concepts, a number of low-level questions need to be formulated, which is less efficient. From this perspective, a high-level question is highly integrated which is able to examine multiple concepts at the same time. Moreover, the level of high order questions can be reduced by cutting the logics between built-in concepts.

Table 1. Explanation of Bloom's Taxonomy[9]–[12].

Degree of learning	Key words
Creation	assemble, combine, compose, construct, design, investigate, predict, produce, synthesize
Evaluation	appraise, argue, assess, confirm, contrast, compare, critique, defend, determine, evaluate, judge, justify, select, verify
Analysis	categorize, diagnose, differentiate, distinguish between, separate
Application	calculate, compute, employ, use, operate,
Understanding	clarify, describe, explain, illustrate, interpret, paraphrase, summarize, translate
Remembering	define, duplicate, identify, label, list, mention, memorize, outline, recall, recognize, recite, repeat, restate,

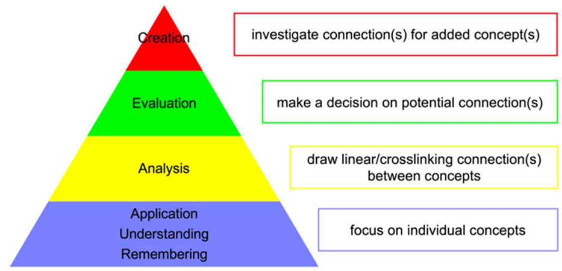

Figure 1. Characteristics of prepared questions for each level of learning on a basis of Bloom's Taxonomy.

A. Analysis level (AL) Questions

In terms of calculation, both analysis and application level convey straightforward given conditions where students can effortlessly tell the goal of calculation from a question itself. The difference between these two levels is that questions in the application are a kind of 'plug and play' format with no more and no less given information since they are designed for a specific condition or an equation in the textbook. Therefore, this level requests one or two steps of calculation. By contrast, analysis-level questions require an analysis of logical relationship between knowns prior to calculations with multiple steps. The number of concepts and equations as well as the logics between them is controllable dependent on the complexity as preferred by a question-designer. Typically, the more links, the more complicated the calculation results in. An example question (EQ) is placed below.

ALEQ 1 (PDP-MW)

> A polymer-forming reaction network includes: $A + B -> P$, $A + P_B -> P$, (3) $B + P_A -> P$, and $P_A + P_B -> P$ with respective rate constants (1.1, 1.0, 1.0, 0.5 $\mathrm{L/mol/s}$) where the mol units are in terms of functional groups (not molecules). The functionalities of A and B are 3 and 2.1. The concentrations (and initial concentrations) in mol/L of A, B, and P are 0.4 (1.0), 0.8 (1.0), and 0.02 (0), respectively. The average MW of A and B monomer are 1100 and 284 g/mol. What is the average MW of the polymers that have formed in this system?

In this case, students are asked to calculate the average molecular weight (MW) of the polymer formed by a reaction of monomer A and monomer B. They first need to get the monomer-free degree of polymerization (PDP) by using a given formula (1) from the textbook and then investigate the molecular weight contribution from two monomers which is not given (4). If this question is modified to ask only for the PDP, then, it decreases to the application level.

Steps of calculation

$$PDP = \frac{(C_{A0} - C_A) + (C_{B0} - C_B)}{C_{polymer}} = \frac{(1-0.4)+(1-0.8)}{0.02} = 40 \text{ (given formula)} \quad (1)$$

$$\Delta C_A = 1 - 0.4 = 0.6 \quad (2)$$

$$\Delta C_B = 1 - 0.8 = 0.2 \quad (3)$$

$$Avg.MW = PDP \cdot \left(1100 \cdot \frac{\Delta C_A}{\Delta C_A + \Delta C_B} + 284 \cdot \frac{\Delta C_B}{\Delta C_A + \Delta C_B}\right) = 40\left(1100 \cdot \frac{0.6}{0.8} + 284 \cdot \frac{0.2}{0.8}\right) = 35840 \quad (4)$$

Such a question shown in ‘Blackboard’ looks like this.

> A polymer-forming reaction network includes: $A + B -> P$, $A + P_B -> P$, (3) $B + P_A -> P$, and $P_A + P_B -> P$ with respective rate constants (1.1, 1.0, 1.0, 0.5 L/mol/s) where the mol units are in terms of functional groups (not molecules). The functionalities of A and B are 3 and 2.1. The concentrations (and initial concentrations) in mol/L of A, B, and P are [X] (1.0), [Y] (1.0), and [Z] (0), respectively. The average MW of A and B monomer are [α] and [β] g/mol. What is the average MW of the polymers that have formed in this system?
>
> Answer: $\frac{2-(X+Y)}{Z} \cdot (\alpha \cdot \frac{1-X}{2-(X+Y)} + \beta \cdot \frac{1-Y}{2-(X+Y)})$ with the range of $(0 < \mathrm{X, Y, and\ Z} < 1; \alpha \text{ and } \beta > 200)$
>
> Feedback:
> How to calculate PDP?
> How much is molecular weight contributed by the A monomer and B monomer?

Table 2 summarizes the ways of inputting solutions on platforms. Although the first one ‘Calculated Numeric’ is theoretically fit for any level of question, it is not recommended since a numeric answer is merely valid for one question resulting in an overwhelming burden of preparing a great many questions. Therefore, the second method is mostly utilized by educators except for programming questions.

Table 2. Format of inputting solutions on platforms

format	valid for	pros(+) and cons(-)
Calculated Numeric	any type of question with numeric answer	(+) easy, fast, and accurate to prepare a couple of questions (-) overwhelming task for preparing a large number of questions
Calculated formula	Calculations by use of equation(s)	(+) accurate and less burden to prepare solutions for a large number of equational questions (-) unable to solve programming questions
Calculated Formula fitted graph	An empirical equation fit to a series of answers (e.g. from *Matlab* code)	(+) extremely versatile (can be used for a complex programming code) (-) time consuming and inherent error in solution

A proper feedback should be given to students getting incorrect answers (Figure 2 and Table 3). Nevertheless, its format may vary in expectations by a professor. If the expected achievement is solely on applying a formula or even lower levels of learning, the complete steps of calculation are quite eligible. By contrast, the primary goal of high level of learning is to give students a chance to think about the reason for each step in solving a question instead of concentrating on the solution itself. With the feedback, students start to figure out their issues in calculation until the correct answer. Instructors could provide participants 3 repetitions. After which, a detailed solution is suggested to be given to students who are hardly to work out or the ones who are likely to review previous questions for the next test.

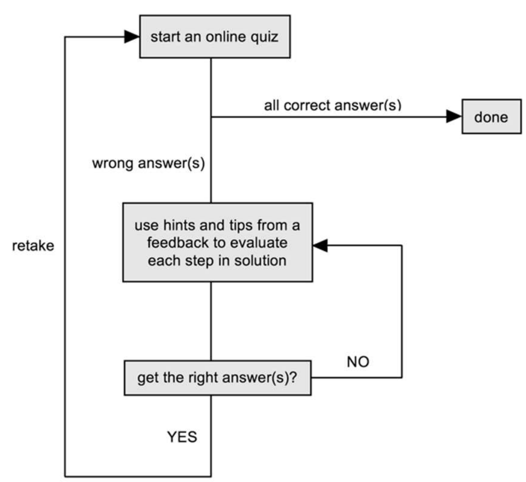

Figure 2. A block diagram of how students learn from online quiz question(s).

Table 3. Layout of Feedback

Creation Evaluation Analysis	• use of hints or tips for each key step to proceed calculations • in the format of asking
Application Understanding Remembering	• clear answer in words • exact formula(s)

ALEQ 2 (modify a simple code)
It is available for students to copy, paste, and execute a given Matlab programming code in seconds. However, they are requested to analyze and identify which parameter is going to be changed, and finally understand the output. The design of this type of question is quite flexible. The source of question material can be from polymer reaction engineering, chemical engineering, or any field as long as the parameter could be numerically expressed. In the following example, 'fa' represents the functionality defined as the total number of functional groups of a reactant per mole. the polymer concentration is zero at the critical conversion, which means that the reacting system reaches the gel reaction time where the viscosity goes to infinity and eventually forms a whole macromolecule.

> A polymer-forming reaction network includes: A+A→P; A+P_A →P; P_A+ P_A→P. A script file of the simulation program is: global fa k; fa=3; k=[5E-3 5E-3 5E-3]; [t,ct]=ode45('polymer', [0:0.01:90], [1 0 fa*1]); with a corresponding function file: function ydot=polymer(~,c) global fa k; CPA=c(3)-fa*c(1); r=[k(1)*fa.^2*c(1).^2, k(2)*fa*c(1)*CPA, k(3)*CPA.^2]; ydot=[-r(1)-r(2), r(1)-r(3), -sum(r)]; ydot=ydot'; What is the time at which critical conversion is reached if the functionality is 3.05?
>
> Answer: 77.67 (s)

Table 4. Output of Matlab code for ALEQ 2 when fa=3.05

time (s)	monomer A conc.	polymer conc.	A moiety conc.
0	1.0000	0	3.0500
⋮	⋮	⋮	⋮
50.0000	0.1640	0.2411	1.9002
⋮	⋮	⋮	⋮
77.6700	0.0794	0.0000	1.5567

Unlike the previous example in making solutions, Blackboard and Canvas are not able to run the code for programming questions. Based on this concern, a fitted-graph is going to be employed to generate an empirical equation presented in Figure 3 with different functionalities. It needs to be mentioned that sometimes, online platforms get the answer from a formula with a small deviation albeit perfect regression ($R^2 = 1$). Thus, it is suggested to provide a slight range for correction, say 0.5 per cent.

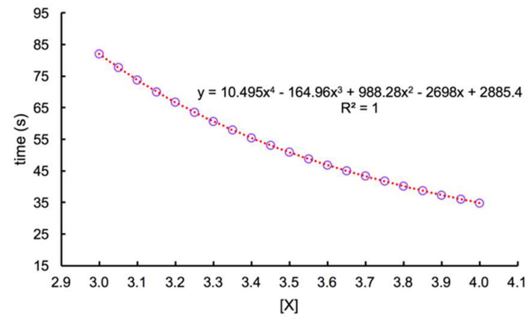

Figure 3. A fitted-graph to provide an equation for solutions for ALEQ 2. The symbol 'O' represents the output of Matlab code. '[X]' is the functionality.

> What is the time at which critical conversion is reached if the functionality is $[X]$?
>
> Answer: $10.495X^4 - 164.96X^3 + 988.28X^2 - 2698X + 2885.4 \pm 0.5\%$ $(3.0 \leq X \leq 4.0)$
>
> Feedback:
> Which line in the code is the expression of functionality? Please be aware of the meaning for each column in the output.

The following examples are going to be displayed with variable(s).

B. Evaluation level (EL) Questions

In engineering courses, evaluation-level questions are commonly about making decisions either based upon a requirement (Example 1) or to achieve a goal like optimization (Example 2) for which the decision starts with identifying the part of the system to be modified for a desired result. With this context, this level of question can be prepared from the Analysis Level by inserting two components: (1) identification of important parameters and which ones to be modified, and (2) how these parameters are changed to achieve a desired outcome.

ELEQ 1

> A homogeneous reaction in liquid phase at constant density occurs with A reacting to form B and is first order in A (only A in reaction rate expression). The initial molarity of A is [X], the reaction rate constant is [Y]. The system should be designed for an average flow rate of [Z] liter/hr. What is the volume of the reactor choosing the SMALLEST one from (1) Batch reactor; (2) CSTR reactor; (3) Plug-Flow reactor (PFR) to achieve a final molarity of A of [K]? Units in this problem and for the answer are to be in moles, liter, and hour as appropriate for each term. If the reactor is a batch reactor, add two hours for turn-around. The answer (e.g.

11024.45) consists of two parts: the first being a decision among given optional reactors (e.g. 1*10000) and the second being a numeric value (e.g. 1024.45).

Answer: $V_{PFR} = \left(\frac{-[Z]}{[Y]} ln^{\left(1-\frac{[X]-[K]}{[X]}\right)} + 3 \times 10^4\right) \pm 0.5\%$

Feedback:
which reactor could have the minimum volume?
how to integrate the design equation in terms of conversion?
what is the unit of flow rate?

The times to perform an online question impacts its true level of assessment, which is frequently overlooked. When students study for an exam by simply reviewing previous years' and memorizing a limited number of variations, such a testing process becomes memorization. Likewise, if a student is exposed too many times, the question becomes a memorization as oppose to evaluation level. For instance, at the first time, the example question above is definitely at evaluation level. After that, the level turns to be lower because students get to know that the smallest reactor typically aims for the PFR, which is easy to be remembered for repetition and once this question appears in the second time with only change in variables, they probably race to the PFR neglecting the process of justifying and making a decision. Then, the cognitive level of this question drops from the evaluation to analysis or application level.

Thus, the ways to survive a high-level question before it becomes a memorization needs to be carefully studied. The level of reduction depends on not only the number of times that students have seen a question, but also the complexity of the question itself. A simple question goes down from evaluation level after one or two exposures while a complicated one could still remain at such a level after being taken 4 or 5 times.

There is a fact that no matter how complex a question is made, as long as students see it, making mistakes at the first time, and with the help of feedback to figure the mechanism behind the question, they start to be familiar with this pattern. The question probably dies from two repetitions. This is true. Sometimes, educators are struggling with themselves for that on the one hand, they are eager to see that students are able to solve a well-prepared question, dig the principle underneath out, and eventually truly learn from it; on the other hand, by doing so, the question lives shortly and teachers have to find a way to survive it from memorization by students, especially for high levels of learning; otherwise, the speed of formulating good questions is hardly catching up with the rate of digestion by students.

To prevent memorization, three methods can be exploited.

To start with, undoubtedly, there is no method better than expansion of a question pool so that each question can only be exposed to students one or two times, which will essentially address this issue through either adding new questions, or taking advantage of existing one but varying ways of asking indicated below.

[Q1] What is the volume of the reactor choosing the LARGEST from (1) Batch reactor; (2) CSTR reactor; (3) PFR to achieve a final molarity of A of [K]?

[Q2] What is the volume of the reactor that has the LOWEST conversion per unit volume from (1) Batch reactor; (2) CSTR reactor; (3) PFR to achieve a final molarity of A of [K]?

[Q3] What is the volume of the reactor that has the HIGHEST conversion per unit volume from (1) Batch reactor; (2) CSTR reactor; (3) PFR to achieve a final molarity of A of [K]?

In a result, students have to take the quizzes at least four times to be fully familiar with this question. Similarly, for the ALEQ 2, one could ask the following:

[Q1] What is the concentration of A monomer at which critical conversion is reached if the functionality is $[X]$?

[Q2] What is the concentration of A moiety at gel reaction time if the functionality is $[X]$?

[Q3] What is the concentration of (A monomer/Polymer/A moiety) at 25 seconds?

[Q4] What is the concentration of (A monomer/Polymer/A moiety) if the polymer-polymer reaction rate constant is 0.088?

This approach enables professors to save a huge amount of time for question preparation and to effectively increase the number of times that students have to take the quizzes before the question reduces its level to be memorization.

Besides, educators could recall the questions that have already been taken several weeks ago towards the goal of strengthening critical topics throughout the course.

Another way is to increase the number of variables, options or conditions to choose or judge. This method could be used in combination with the first one. The following examples in solving partial differential equation via a Matlab function-PDEPE frequently used by students in Chemical Engineering is prepared to contain 8 variables, which is rather difficult to be memorized shortly. Beyond these, multiple assumed situations could be assigned. For each question, students necessitate to evaluate the specific condition and make a decision for the target variable(s) before calculation.

ELEQ 2

you are to answer this question with a number between 100 and 900 where the first digit (number in 100 space) refers to the variable in the sequence and the next two digits refer to a value for that number. For example, to change the value of s to 3, you would enter the answer 303. By entering 303 you are indicating that you would change the value of variable 3 (s) from a value of 0 to a value of 3.

A PDEPE file was set up to simulate the temperature profile of a metal rod using the following specifications of the differential equation, the initial condition, and the boundary conditions: 1) c = 5; 2) f = DuDx; 3) s = 0; 4) u0 = 25; 5) pl = 5; 6) ql = 1; 7) pr = 0; and 8)qr = 1. How would the boundary condition equation specification change to reflect a metal rod with a thermal conductivity of [X] (J/s/K/cm) and a heat flux is provided by at 100% efficiency from [U] V DC and a resistance of [Y] Ohms entering a [Z] square cm surface?

Answer: 500+$\frac{U^2}{XYZ}$

Feedback: The left boundary condition is (heat flux)/(thermal conductivity) which is set up by 5 (pl). Therefore, the first digit in the answer is 5. Heat flux from a resistor heating source is equal to $\frac{U^2}{RA}$ where R is the resistance in ohms and A is the area in cm^2.

More questions could be built on this structure

[Q1] How to change this program to set up a left side boundary condition that has a heat flux that is $[X]$% of the value used in this benchmark case?

[Q2] How to change this program to set the initial temperature of the metal rod at $[X]$K?

[Q3] How to change this program to set up a right side boundary condition where (heat flux) divide by (thermal conductivity) is $[X]$ from the system? Note that on the right side, a positive number reflects heat out of the system.

[Q4] How would the partial differential equation specification change if the metal rod had the following conditions: a thermal conductivity of $[X]$(J/s/K/cm), a density of $[Y]$(g/cm^3), and a heat capacity of $[Z]$(J/g/K)?

[Q5] How would the boundary condition change to reflect a metal rod with a thermal conductivity of $[X]$(J/s/K/cm) and a heat flux from the left of $[Y]$(J/cm^2/s)

C. Creation-level (CL) Questions

Both analysis-level and evaluation-level questions in Matlab emphasize on the comprehension of a given code with no change in built-in logics. So the variations between these questions lie in different values of variables. Nonetheless, to solve a creation-level question, students are encouraged to make a new logic to link the unknown with known without any obvious indication for a new outcome. For example, in ALEQ 2, there is no change in the relationship between the functionality, reaction rates, reaction rate constants and concentrations of A monomer, A moiety, and the polymer. To upgrade the level, a new logic could be designed as adding a solvent to the current isothermal reaction (example 1) or to be under non-isothermal condition (example 2), or both.

CLEQ 1 (adding solvent to a reacting system of ALEQ 2)

If a solvent ($[X]$ grams, 0.87 g/cc) is added to the system (100 grams, 1 g/cc). What is the concentration of A moiety at 20 seconds? Report FOUR digits to the right of the decimal point.

Answer: $(1E-04X^2-0.0195X+2.3706)\pm 0.5\%\ (27.0\le X\le 37.0)$

Feedback:
How would the initial concentration change with added solvent?

Note: The primary influence of a solvent is to dilute the reagents slowing down the reaction rates so as to correct the initial concentration: $V=100/\ (100+\ mass\ of\ a\ solvent/0.87)$; $c0=\ [V,0,fa*V]$; Then execute the new code and check the A moiety concentration at certain time.

ELEQ 2 (an isothermal chemical reaction to non-isothermal)

A program with script: global k; k=1E-2; [t,ct]=ode45('reaction',[0:100],[1]);and a corresponding function file: function ydot=reaction(~,c); global k; r1=k.* c(1); ydot(1)=-r1; ydot=ydot'; What is the reaction temperature at 240 seconds for an adiabatic simulation on a basis of 1 liter includes the following conditions: initial temperature (298 K), activation energy ($[X]$ J/mol), hrxn/mCp (-46.47 ℃/mol)? Report FOUR digits to the right of the decimal point.

Answer: $(340.4374 - 0.0038X) \pm 0.5\%$ $(30.0 \leq X \leq 40.0)$

Feedback:
How would the reaction rate constant(s) change with the temperature?
How to express the change of temperature by using given conditions?

Note: The Arrhenius equation is used to achieve the change of reaction rate constant(s) with the temperature which could be expressed by $\frac{dT}{dt} = \frac{V \cdot H_{rxn} \cdot r_{rxn}}{m \cdot C_P}$.

The mechanism to design a question at creation level can be the same as building blocks. It is full of flexibility and possibility. To illustrate, the conditions- an influence of a solvent and non-isothermal reaction, are shown in two questions, respectively, but they could also be present in one question simultaneously. The benefit of this random modular approach is not just to maintain the question pool with a high degree of variability. It can greatly shorten the time for question preparation. Beyond these, with such a type of training, students are going to be concerned about given conditions instead of the question itself. They realize that a solvent is related to the concentration of reactants and how to deal with a non-isothermal reaction. This is the key to cultivating their flexible use of knowledge they have learned, which is of notable significance in future study and practical work, especially for engineers.

III. SUMMARY

Factual information can be acquired on the Internet by ‘one click’ in Google. Modern requirements for graduates have transferred from a recollection of concepts and equations to logical thinking and creative ability. Such a change poses a higher demand for educators who are going to correspondingly establish a higher level of objective to guide students towards the new goal of learning.

To reach an achievement, the skills of formulating high-order learning questions for online use are illustrated in detail. By inserting the process of identification on targeted parameters, an evaluation-level question builds on the analysis level which asks for recognizing the connections among concepts. A question in creation level necessitates students to come up with an idea to deal with new concepts added to the current condition for a new output. To prevent a question reducing its level after one or two exposures, instructors can either recall it several weeks later or expand the pool by new questions or modifying current ones via creating more situations, increasing the number of variables, and various ways of making requests.

NOMENCLATURE

avg.= average
ALEQ= analysis-level example question
c, conc.= concentration [mol/l]
C_{A0}= initial concentration of A monomer [mol/l]
C_A= concentration of A monomer [mol/l]
ΔC_A= concentration difference in A monomer [mol/l]
C_{B0}= initial concentration of B monomer [mol/l]
C_P=heat capacity [J/(mol · ℃)]
CSTR= continuous flow stirred-tank reactor
e.g.=for example
ELEQ= evaluation-level example question
fa=functionality
hrxn=heat of reaction [J/g]
k= reaction rate constant [l/(mol · s)]
m=mass [g]
MW=molecular weight [g/mol]
P=polymer
P_A= A moiety on polymer [mole]
P_B= B moiety on polymer [mole]
PDP= polymer degree of freedom or monomer-free degree of polymerization
PFR=plug flow reactor
Q=question
r= reaction rate [mol/(l · s)]

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