Is there a Transition Flux?

Incorporating a Research Element into an Undergraduate Engineering Laboratory

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Background

The modern student is generally trained to recall information but in many cases cannot think independently and does not show initiative. While the secondary school curriculum is a major factor in this regard, it must be said that large parts of the third level experience perpetuate this problem. Increased use of active learning, problem based learning and research-based learning should help to encourage independent thinking. In most degree courses in Engineering/Science, a final year project is the first true taste of scientific research encountered by undergraduate students. The final year research project can often prove an extremely daunting task, and the amount of time and effort required by the undergraduate student to settle into this new type of work can be detrimental to the work of the student on core subjects that are assessed by written examination. Incorporating a research element into undergraduate modules should prove advantageous on at least two levels – the student will be better prepared for the final year research assignment, and the less prescriptive approach should encourage student participation and a greater measure of independent thinking.
In this study, a group of 3rd year biotechnology students was presented with a hypothesis for consideration a s part of an engineering laboratory module.

Implementation

A hypothesis was presented to the students - the problem was designed to be authentic, stimulating the students interest and incorporating material previously covered in lectures thus reinforcing learning outcomes. Students were provided with a lab manual outlining the theoretical background to the problem, and enquiry and self directed learning was encouraged by provision of a demonstrator and appropriate materials to address issues encountered.

Theoretical Background

Modelling the dynamics of flux decline in crossflow microfiltration is a difficult problem for which no solution has been found at present. One of the more popular, and simple, approaches to this problem is to modify dead-end filtration theory by incorporating a cake removal term, or cake removal constant that will depend on the crossflow velocity.

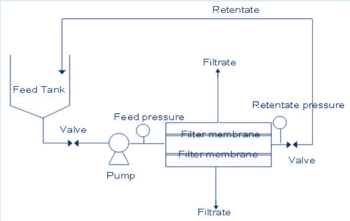
$$\frac{dm}{dt} = cJ - Km$$

Problems with the Popular Approach
Reversibility: If we do an experiment in which we allow the cake to build up, and then replace our feed with a pure water feed, the model suggests that in this case the cake mass will decline exponentially to zero and in the absence of membrane fouling (changes in R_m) the flux will return to its original value. However, in practice, we rarely find that this occurs.

$$\frac{dm}{dt} = -Km$$

Particle Size: The second problem with this approach is that it makes no mention of the role of particle size in the deposition process. A key concept in the theory of crossflow microfiltration was the idea of a critical flux. By analyzing the forces acting on a depositing particle, it can be shown that the deposition of a particle depends on the relative magnitudes of the normal and tangential forces acting on the particle as it deposits.

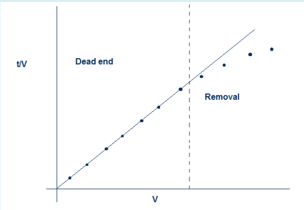
Crossflow Filtration



Hypothesis

The students are introduced to a modified model for crossflow microfiltration incorporating a term representing a **transition flux**.
Hypothesis: There exists a transition flux below which cake removal occurs.
If the flux is above the transition flux, cake formation proceeds exactly as in dead-end filtration. Thus in a constant pressure process, the flux could start off above the transition flux and as the flux declines, it may becomes less than the transition flux and cake removal will then begin. One of the advantages of this approach is that it takes care of the issue of reversibility. If for example, our steady state flux is below the transition flux and we change our feed to pure water, the cake will be removed but only until the flux returns to the transition value. At this point, no more cake will be removed and thus the membrane will never become perfectly clean.

Transition Flux



Assessment

The students were assessed on the basis of their laboratory reports. Each student produced an independent report. Students were expected to produce the report in the style of a scientific journal article and were encouraged to access e-journals via the library website.

Student Results

The group of 16 students was divided into 5 groups and each group performed a distinct set of experiments to test the hypothesis provided. Only 1 group found evidence of a transition flux from their experimental data. 73% of students reported that they had expected to find a transition flux in their data , indicating that they had understood the process of performing research by proposing a hypothesis and performing experiments to prove or disprove their theory. All students reported that further experimentation was necessary to support their initial results indicating that they grasped the limitations of the time-constrained laboratory session.

Reflections

By adopting this approach to teaching in the laboratory, students are introduced at an earlier stage to the skills needed to conduct meaningful scientific research. In particular, it encourages students to evaluate experimental data without bias. By performing experiments for which the outcome is not known in advance, student interest and enthusiasm is significantly increased.

The quality of student reports varied widely throughout the group. 27% of students did not seem to grasp the point of the exercise and simply reported their experimental results. However it was clear from the report structure and presentation of experimental data and results, that in many cases the students engaged well in the process to an extent which had not been observable in previous laboratory sessions.

Further work will include the incorporation of research problems at an earlier level than 3rd year, ideally at first year level. In this study, the hypothesis was provided for the students – student engagement may be further enhanced by requiring students to come up with their own hypothesis on the basis of the theory, prior to the laboratory session.