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Feedback in Complex, Authentic, Industrially Situated Engineering Projects using Episodes as a Discourse Analysis Framework – Year 3

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Introduction

Over the last ten years, we have developed, implemented, and studied student learning in cyber-enabled learning systems.[1,2] Central to each of these learning systems is a virtual process that enables a team of students to develop, test, and refine solutions as they are tasked with developing an optimal "recipe" for one of two reactors. The two virtual reactors include: the Virtual Chemical Vapor Deposition (VCVD) Reactor, a simulation of an industrial-scale chemical vapor deposition (CVD) reactor, and the Virtual Bio Reactor (VBioR), based on an industrial scale bioreactor process. These learning systems provide students a capstone experience in which they can apply experimental design in a context similar to that of a practicing engineer.

Throughout students' engagement with a learning system, student teams meet with an instructor, called the coach. The student-coach interactions are different from those in traditional classroom settings. Teams and the coach interact in semi-structured design meetings, called coaching sessions, which mirror the structure of industrial design reviews. Students take on the role of process development engineers while the coach acts as mentor and manager. We have learned that feedback provided by the coach during these interactions is critical to the success of the learning systems.[3] For effective implementation of these learning systems at other institutions, there is a need to describe the characteristics of successful feedback and the effects of that feedback on student learning. This poster will present the current findings of the investigation into the nature of the feedback provided by the coach to the student teams, and the relationship of that feedback to the strategies students apply as they engage in the task, the models they develop, and their knowledge integration of material from previous courses. Specifically, the research questions for this stage of the study are:

1. What are the different types of feedback coaches provide and what characteristics distinguish the different types of feedback?
2. What is the relationship between coach feedback and the development of the experimental models and strategies students apply as they work to complete the assigned task?

Feedback

Feedback is an essential tool used by instructors to close the gap between current performance and desired performance. In education, it takes many forms, including interactions both inside and outside the classroom. Feedback inside the classroom has been found to have a strong connection to student performance and learning.[4] According to a meta-analysis by Hattie and Timperely, the effect size of feedback is among the highest of all educational factors, weighted heavier than such factors as students' prior cognitive ability, socioeconomic status, and reduction in class size.[5] They describe feedback as a process where teachers make learning goals clear to students, help students ascertain where they are relative to those goals, and then assist students in moving their progress forward. However, there is no general consensus as to what specific attributes of feedback lead to improved learning, and multiple lines of research emphasize that appropriate feedback is specific to the learning context of the student and/or task.[6] Researchers have advocated that feedback works best when it directs student attention to appropriate goals and actions,[7] and encourages student reflection.[8] Others believe that students are most receptive to feedback when they are sure their answer is correct, only to learn later that it was wrong.[9] Additional factors include a student's understanding of and agreement with the feedback provided, the motivation the feedback provides, and the limits on the student's cognitive load.[10]

Instructional Design

The instructional design is intended to provide an authentic environment where the ability to learn is coupled with the ability to use knowledge in a practical context. The task is posed in the same context as that which engineers would encounter in practice. Teams of students are asked to take the role of process development engineers and optimize the performance of a set of reactors based on experimentation. In completing the task, students engage in iterative experimental design as they seek to find the optimum parameters for the engineering process by changing input parameters and examining output measurements. To better reflect the behavior in real reactors, random process and measurement variation and systematic variation are added to the data from the simulation output that students analyze. Simulating the physical operation of the process and metrology equipment greatly simplifies the act of performing experiments. Therefore, it allows a student to experience a different emphasis on the experimental design process than he/she typically encounters in a physical laboratory. In this way, the Virtual CVD Reactor provides the instructor a tool to scaffold cognitive demand and afford the students an opportunity to more closely follow the iterative process of experimental design that is used by professionals in practice.[1,2]

The instructional activities are constructed around principles of scaffolding, coaching, reflection, articulation, and exploration.[1] A summary of activities for the student teams is shown in Table 1 together with the appropriate instructor- student interactions. The project is introduced in 2-3 lecture periods, where the instructor presents the project task, the framework for the project, general technical background about the industrial context and some of the relevant engineering science, and the project deliverables and timeline. At this time, the students are also provided a design notebook and asked to record activity, keeping track of the run parameters, data analysis, interpretation, and conclusions and decisions from the interpretation. This reflective activity is intended to help the student teams formulate analysis and design strategies. As such, the notebook becomes an artifact with which the team interacts to produce learning.

Table 1: The timeline of the *Industrially Situated Virtual Laboratory Project*

Timeline	**Key Elements**	**Instructor-Student Interaction**
Project Introduction	• Goals of the task are introduced • Criteria for success are indicated	Instructor delivers a presentation introducing integrated circuit manufacturing, some engineering science background, the virtual CVD software interface, and presents the objectives for the task and the deliverables.
End of Week 1	• Design Meeting (DM) o Initial run parameters o Experimental strategy	Student teams meet with the instructor to discuss their design strategy. If initial parameters and strategy are acceptable, the instructor provides students with username and password to access the Virtual CVD laboratory.
End of Week 2	• Update Meeting (TUM) o Progress to date	Student teams meet with the instructor to discuss progress to date, any issues they may have, and the direction they are going.
End of Week 3	• Final Recipe • Final Report • Final Oral Presentation • Design Notebook	Teams deliver a 10-15 minute oral presentation to the instructor, two other faculty members, and the other students in the laboratory section. The presentation is followed by a 10-15 minute question and answer session.

Next, the student team develops its initial design strategy. This element directs students to an information gathering/problem scoping phase that places unusual responsibility on the students themselves to formulate the problem. This formulation evolves during a 20-30-minute *Design Meeting* (DM) through discourse between the student team and a faculty instructor, the domain expert, who acts in the role of manager and mentor. At this meeting, the students must deliver a memorandum that specifies the parameters for their first run, a strategy for subsequent runs, the approach to evaluate the experimental data from the runs, and a virtual budget for the entire project. In developing their initial design strategy, students both search the literature to obtain reasonable reactor parameters and integrate prior knowledge from a diverse set of courses ranging from material balances and reaction kinetics to applied statistics and experimental design. During the meeting, the instructor provides feedback by asking questions that guide the students in developing features of their strategy, initial parameters, and budget that they have not appropriately addressed. The instructor feedback is carefully calibrated to engage the students in identifying the gaps in their current design and to direct their thinking on how they can address those gaps rather than simply correcting errors in the students' approach. The team must have its design approved (typically after a revision) before they are allowed to run experiments in the virtual laboratory.

The team then undergoes the process of iterative experimental design by planning experiments, analyzing data, developing models, and identifying strategies. This process is punctuated by a *Team Update Meeting* (TUM) with the team and the instructor, which has a similar structure to the first meeting. Finally, the team submits a process recipe (or multiple recipes for multiple reactors) for release to high volume manufacturing and presents an oral and written report. After the ten-minute oral presentation, an interactive questioning process between the team and the instructors and the other members of the class provides the final opportunity for students to synthesize their understanding.

Data Collection

During the first two years of the project, data have been collected from video of team-instructor interactions, student team "think-aloud" protocol, student surveys, student work products and interviews. A subset of that data has been transcribed and analyzed with respect to the interpretation of instructor feedback. This research was approved by the institutional review board and all participants signed informed consent forms.

The following data have been collected from the first two years of the project:

1. **Team-Instructor Interaction Video:** During the project teams receive feedback from the instructor, referred to as the coach, through their work on this project. These interactions, called coaching sessions, were recorded for every team that consented. Each coaching session was video recorded from two angles, one intended to capture the actions of the students and the other intended to capture the actions of the coach. Put together, 48 teams have been video recorded during design coaching meetings, update meetings, and the final report presentations.

2. **Project Audio and Post-Project Interview:** During the two years of this project, seven teams (two virtual bio reactor teams and five virtual CVD teams), were observed and recorded throughout the project (average 25 hours/team). The researchers observed, took

field notes, and audio recorded the teams at all times two or more members worked on the project. The members of these teams were invited to participate in an hour long post project interview. In these interviews, students were asked questions about their overall experience, their team's solution pathway, their experience as a member of a team, and their experience as a part of this research study.

3. **Meeting Reflection:** A three question reflection was given to the student teams following their first coaching session. The questions were designed to encourage students to reflect on the important facets of the meeting with respect to the project and to gain insight into what the team gained from that meeting. Students were instructed to complete the survey as individuals before discussing their points as a team. In total, 248 meeting reflections were collected in years 1 and 2.

4. **Surveys (Year 2)** Five surveys have been delivered. One at the start of the senior laboratory course, one after each of the three laboratory projects, and one after the course. They assess motivational orientation (task orientation, ego orientation, work avoidance), students' perceptions of the engineering classroom climate (learning focused, ability-meritocracy focused, cooperative), interest in engineering, and satisfaction with learning in the Virtual CVD task and in the course. The comparative surveys include items assessing perceptions of the Virtual CVD task's authenticity as compared to the course's physical laboratories.

5. **Post Project Survey (Year 1):** A survey has been developed to describe the differing student perceptions of learning that they were able to take away from the three laboratory experiences, two physical laboratories and the virtual laboratory (CVD or BioR). This survey was delivered to the students as an assignment. The survey questions were asked immediately following the completion of each laboratory, though in some cases there was overlap between the delivery of the survey and the start of the next laboratory. Collectively, 116 surveys were conducted.

6. **Experimental Run Log:** A log of all runs made in the virtual laboratory projects is saved as the project progresses. This data is available through the instructor interface and provide an important reference point when generating model maps.

Data Analysis

1. **Episodes:** In the virtual laboratory project, student teams meet twice with the coach. The first of these coaching sessions has been coded and analyzed with respect to the episodes framework. Episodes are defined as thematic units of discourse with a central theme, a relatively clear beginning and end, and a substructure of four stages: surveying, probing, guiding and confirmation.[10] This analysis has also been used to inform the characteristics of feedback. These include the categorization of episode themes, the structure and flow of episodes during the coaching session, the stages sub-structure present within individual episodes, and the types of feedback present.

In this project, twenty-seven teams (14 VCVD; 13 VBioR) from the same cohort have been analyzed. Figures 1 and 2 show example timeline of code counts from the first coaching session for a high and low performing VCVD team, respectively.

Figure 1. Timeline of the episodes characterization for a high performing VCVD team.

Differences are observed between the feedback in the two virtual lab projects. These differences appear to be due to different approaches the coach takes to feedback. The VCVD coach tends to nest episodes based on Coaching Objectives within episodes based on Student Engineering Objectives. This approach imbeds the application of scientific principles in the engineering objectives that are desired. It also affords students more influence over the structure and content of the meeting. Conversely, the VBioR coach tends to initiate episodes that are focused on Coaching Objectives, usually Core Technical Content and Concepts that relate to fundamental VBioR material. This allows greater focus on illustrating calculations, graphs or sketches and can guide the students to consider different solution paths and to encourage conceptual learning. Further investigation is needed to determine the benefit of each approach on student performance and learning.

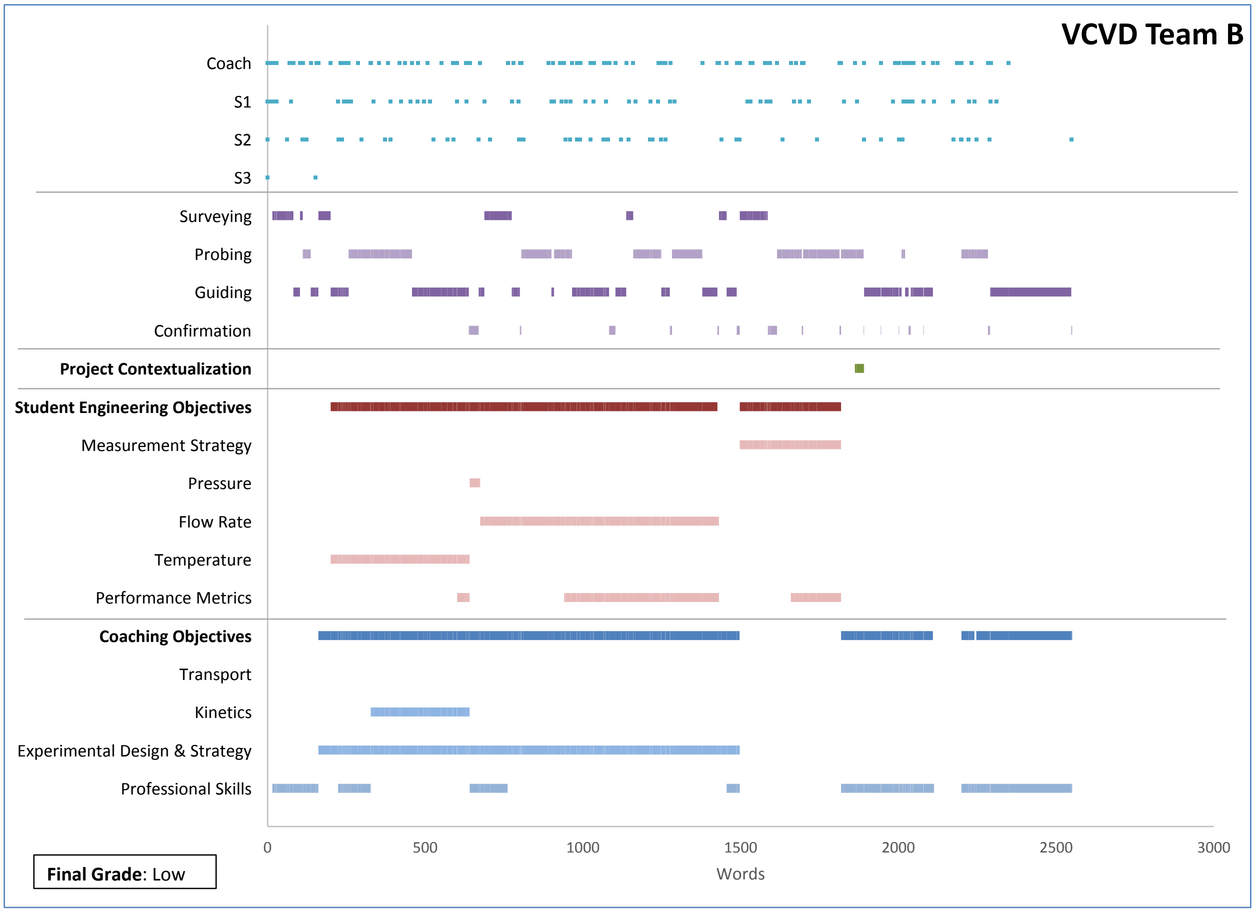

Figure 2. Timeline of the episodes characterization for a low performing VCVD team.

2. **Model Maps:** This research seeks to characterize modeling behavior in student teams with respect to the content and characteristics of feedback in the coaching sessions. Modeling behavior in the virtual laboratory project has been characterized through the generation of model maps. Model maps are a graphical representation of student work products and of their audio recording data, arranged in chronological order.[11] For the Virtual CVD Laboratory, 29 student teams and 3 expert teams have had their work analyzed in the form of a model map. For the Virtual Bioreactor Laboratory, 18 teams have been analyzed. Figures 3 and 4 show example model maps for high and low performing teams, respectively.

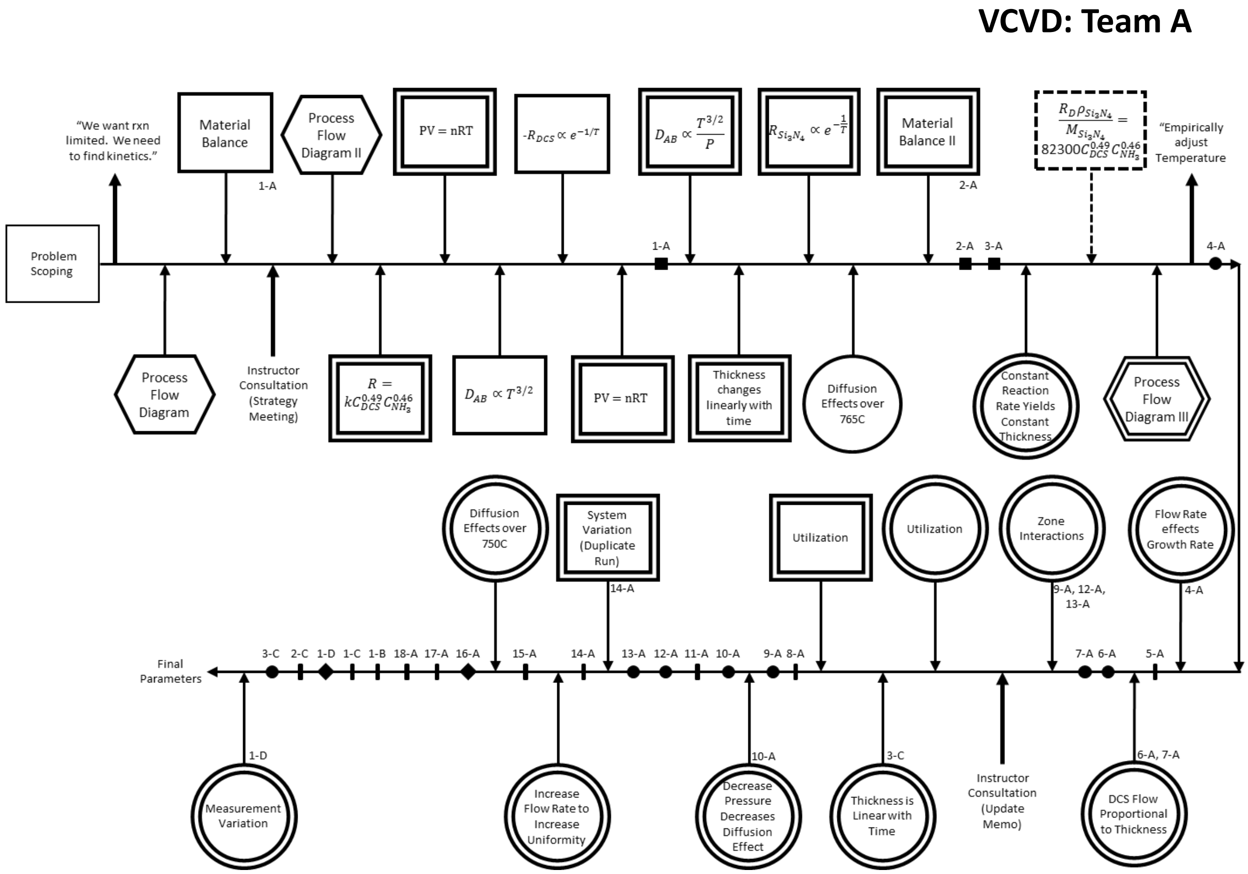

Figure 3. Model map for a high performing VCVD team.

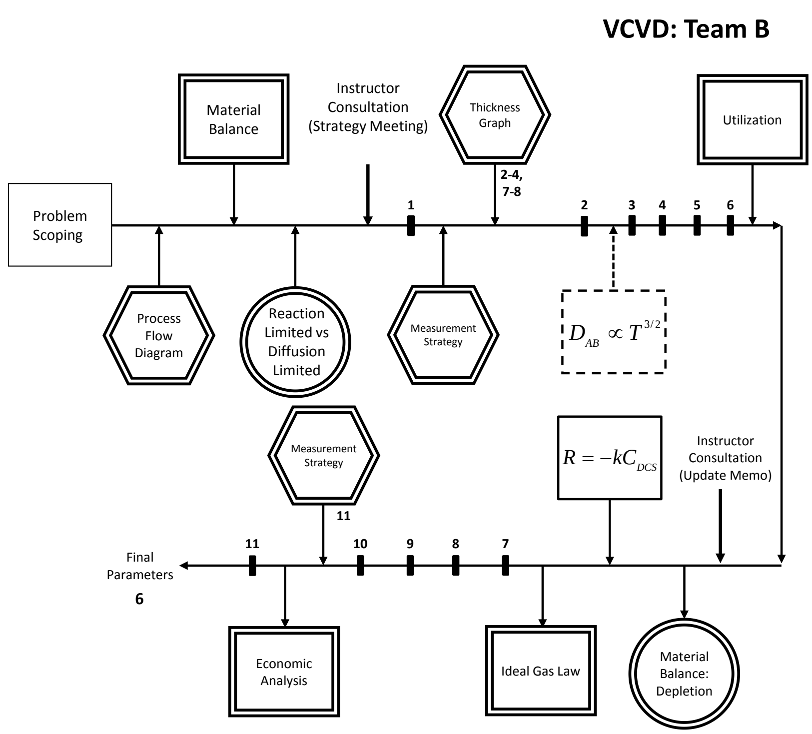

Figure 4. Model map for a low performing VCVD team.

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References

1. Koretsky, M.D., D. Amatore, C. Barnes and S. Kimura. (2008). Enhancement of student learning in experimental design using a virtual laboratory, *IEEE Transactions on Educat*ion, 51(1), 76-85.
2. Koretsky, M.D., Kelly, C. & Gummer, E. (2011). Student Perceptions of Learning in the Laboratory: Comparison of Industrially-situated Virtual Laboratories to Capstone Physical Laboratories. *Journal of Engineering Education*, 100(3), 540–573.
3. Gilbuena, D., B. Sherrett, E. Gummer and M. D. Koretsky. (2011). Understanding feedback in an authentic, ill-structured project through discourse analysis: interaction between student and instructor objectives. *2011 Research in Engineering Education Symposium: Program and Proceedings*, 2011, 700-709.
4. Johnson, G.R. (1979). Verbal Interaction in Junior/Community College and University Classrooms: Do Disciplines and Settings Differ? *Research in Education*, Aug 1979.
5. Hattie, J. & H. Timperley. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81-112.
6. Shute, V.J. (2008). Focus on formative feedback. *Review of Educational Research*, 78(1), 153-189.
7. Kluger, A.N. & A. DeNisi. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, 119(2), 254–284.
8. Bangert-Drowns, R.L., C.C. Kulik, J.A. Kulik, & M.T. Morgan. (1991). The instruction effect of feedback in test-like events. *Review of Educational Research*, 61(2), 218–238.
9. Kulhavy, R.W., & W.A. Stock. (1989). Feedback in written instruction: The place of response certitude. *Educational Psychology Review*, 1(4), 279–308.
10. Gilbuena, D., B. Sherrett, E. Gummer, and M. D. Koretsky. (2011). Episodes as a discourse analysis framework to examine feedback in an industrially situated virtual laboratory project. *Proceedings of the 2011 ASEE Annual Conference & Exposition*, Vancouver, BC, Canada.
11. Seniow, K., E. Nefcy, C. Kelly, & M.D. Koretsky. (2010). Representations of Student Model Development in Virtual Laboratories based on a Cognitive Apprenticeship Instructional Design. *Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition*.