AC 2011-2527: OCCASIONING THE EMERGENCE OF KNOWLEDGE AND PROMOTING MOTIVATION FOR ALL STUDENTS: APPLYING INSTRUCTIONAL PRINCIPLES TO ENGINEERING SITUATIONS

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Occasioning the Emergence of Knowledge and Promoting Motivation for All Students: Applying Instructional Principles to Engineering Situations

Abstract

In this paper, we introduce two sets of instructional principles that can be valuable for new engineering educators, and provide illustrations of how these principles have been embodied in our teaching activities. Our emphasis is not on demonstrating the success of the activities we describe, but rather on using them to illustrate the principles. A key message to be taken from our analysis is that the link to these principles lies not only in the starting activity, but also in how the instructional activity is facilitated over time. In the discussion, we note the relevance of these principles to the current educational climate with its focus on helping larger groups and more diverse groups of students to be successful.

Introduction

As new engineering educators work to become seasoned, effective, and even inspirational educators, searching for instructional principles (i.e., a prescription or an assertion about how to teach) that are situated in research and aligned with the goals one has for one’s own teaching can be challenging. Furthermore, imagining how the principles can be instantiated in teaching situations can be particularly challenging when the examples provided do not map well to one’s specific teaching situation. In such cases, it can be beneficial to simply have more examples available. In this paper, we introduce two sets of instructional principles that we have found particularly useful for guiding our own teaching and provide illustrations of how these principles have been embodied in our teaching activities.

The first set of instructional principles emerges from the field of motivational theory and is documented in the book, Diversity and Motivation: Culturally Responsive Teaching by Wlodkowski and Ginsberg\(^1\). Based on a synthesis of the extensive body of research on motivation and an interest specifically in ensuring that all students have the opportunity to feel motivated to learn, Wlodkowski and Ginsberg identify four instructional principles, each with two associated sub-principles: (1) establish inclusion (though respect and connectedness), (2) develop positive attitudes toward the material (through autonomy and relevance), (3) enhance meaning-making processes (through challenge and engagement), and (4) engender students’ sense of their growing competence (through authenticity of assessment and effectiveness).

The second set of instructional principles emerges from the field of complexity science and is documented in the book Complexity and Education by Davis and Sumara\(^2\). Based on a synthesis of ideas related to complexity theory, with specific attention to creating the conditions that promote the emergence of knowledge, Davis and Sumara identify the following three principles: (1) embrace the tension between diversity and redundancy, (2) provide enabling constraints by balancing coherence and randomness, and (3) promote trans-level learning through neighbor interactions and decentralized control.
In this paper, we provide further detail on these two sets of instructional principles and demonstrate how we have instantiated them in cases situated in two different teaching contexts: (1) an undergraduate course involving technology and design and (2) a graduate course devoted to helping students learn to critically assess research in their field. We anticipate that by introducing new engineering educators to these two powerful sets of instructional principles and illustrating how they can be mapped to educational practice, we will empower these educators to try out new ideas in their own teaching.

**Approach**

We first introduce the two teaching cases that we will be using. The first case, the *squares activity*, was a class exercise used at the beginning of the term with a class of just under 30 undergraduate students. The second case, the *journal landscape project*, was one of three projects assigned in a graduate class of just under 30 students. These two cases are complementary in that they vary in the unit of teaching (class activity versus multi-week project) and in terms of student population (undergraduate versus graduate).

We did not select these cases because of any specific claim to their novelty. In fact, the *squares activity* is a common design exercise. Rather, we selected these cases to illustrate the principles. Moreover, since our emphasis is not on demonstrating the success of these cases, but rather on using them to illustrate the principles, we focus below on explaining how the activities align with the principles rather presenting data to prove the activities worked.

**Case 1: Undergraduate class exercise**

In the *squares activity*, students were invited to engage in a highly constrained design task—specifically, to place four solid black squares against a white field in order to represent the concept of increase. The exercise was an initial assignment in a junior-level course entitled “Communication Design and Rationale.” In general, the goals of the course were to help students gain skills in generating designs, using technology to generate their designs, and providing a rationale for their designs.

In terms of the sequencing over time, students were told of the assignment during one class session and asked to prepare and submit one or more solutions electronically before the next class session. The instructor (the second author) presented the students’ solutions as examples in a lecture during the subsequent class session. During that lecture, students were directed to attend to the variety of solutions created by the class, to ask questions about solutions that interested them, and to discuss how specific solutions might be relevant to specific design situations. With the conversation as a backdrop, students were then introduced to the notion of a design rationale and asked to draft a sample design rationale as a way to introduce them to this concept.

**Case 2: Graduate multi-week project**

The *journal landscape project* was a multi-week project in a graduate level course entitled Empirical Traditions in Human Centered Design and Engineering. Per the syllabus, the task was as follows: “Working in teams of two or three, you and your teammate(s) will characterize one year of articles in a major journal in our field in terms of five to seven dimensions of your
choosing and then prepare a summary of what this characterization reveals.” This project was the initial project of a course whose overall goal was to help incoming graduate students develop their capacity to function as a critical consumer of empirical research. The project, specifically, was designed to get students to interact with journals and journal articles, think about knowledge work broadly, and discover information of interest.

In terms of sequencing over time, the process involved the following:
1. Students were introduced to the assignment on the first day of class and invited to participate in a brainstorming session about journals they might explore and dimensions they might use in characterizing the journal’s articles (e.g., the number and nationality of the authors, features of the overall structure of the article such as whether there is an explicit approach or implication section, the number and age of the citations).
2. Based on this information, students were then asked to form teams around specific journals and prepare a first milestone report (a one-page document) containing their journal name and a list of candidate dimensions. These milestone reports were then used in class to discuss various methodological issues associated with specific possible dimensions (e.g., how to operationalize dimensions of interest, how much time a dimension might take to analyze, the benefits of “double coding”).
3. Based on this information, the students were then asked to prepare a second milestone report (a one-page document) containing a revised set of dimensions and an approach for coding these dimensions. Again, the milestone reports were used, in class, to discuss the project.
4. Two days before the project was due, students were required to (a) give a “minute-madness” presentation to the class on their results and (b) bring a draft of their report to class for peer review.
5. The group then submitted the final report two days later, after making revisions based on the peer review. In addition, individual group members submitted a written reflection on their learning through the project process.

Description, Observation and Reflection

In the next two sections, we further describe these two cases. Specifically, we describe each case in terms of the instructional principles we introduced earlier, starting with the principles related to motivation. Further, our descriptions are augmented by our own observations and reflections on these instructional activities as they transpired in our classes (during the winter 2011 academic term for case 1 and during the fall 2010 term for case 1).

Promoting Motivation for All Students

Motivation—generally speaking, the level of will, want, or desire that someone has toward taking some action—has long been considered an important issue in teaching and learning. A student’s level of motivation relative to class-related activities can affect time on task, ability to persist in the face of difficult tasks, and other factors that are positively linked to learning outcomes. Specific links between motivation and learning have been explored within the realms of self-determination theory, social cognitive theory, and achievement goal theory. For example, self-determination theory suggests that motivation is in relationship to the human needs for relatedness (security and belonging), competence (important for promoting self-worth), and autonomy (control).
Instructional Principles

This work is organized around the framework presented by Wlodkowski and Ginsberg\(^1\). This framework is of interest because it represents a synthesis of much research concerning motivation, is oriented toward higher education, specifically provides educators with teaching practices, emphasizes intrinsic motivation toward educational content, and takes into account both cognitive and social issues related to motivation. Even further, the framework builds on research into culturally aware teaching practices and thus is synergistic with engineering education’s concerns related to diversity. The framework is motivated by a belief that all students have a right to experience intrinsic motivation to learn, and educators can engage in activities that have the potential to contribute to such a goal. The key contribution of their framework is to bring all of these elements together.

Wlodkowski and Ginsberg’s framework is organized around four broad teaching principles: establishing inclusion, developing attitude, establishing meaning and demonstrating competence. In order to help educators work toward each of these principles, Wlodkowski and Ginsberg identify conditions (they use the term criteria) that contribute to the achievement of the principle: educators can establish an inclusive environment through respect and connectedness, help students in that environment develop a positive attitude toward material through relevance and autonomy, help students establish meaning of the material through engagement and challenge, and help students demonstrate competence relative to the material through authenticity and effectiveness. In their book, the authors further unpack each principle by proposing “norms” that contribute to the achievement of the principle, identifying example teaching “procedures,” explaining the theoretical basis of each of these ideas, and unpacking the link between these ideas and issues of multi-cultural teaching. They also clearly acknowledge the overlapping nature of these elements.

**Establish Inclusion: Respect and Connectedness**. The key idea of this principle is that those participants in a group who feel included are more likely to be committed to the practices of the group, in this case, learning practices. In particular, Wlodkowski and Ginsberg identify respect and connectedness as two conditions that contribute to inclusiveness. In terms of respect, Wlodkowski and Ginsberg state, “We understand respect in the learning environment to mean that the integrity of each person is valued in ways that welcome the worth and expression of one’s true self without fear of threat or blame” (p. 62). We interpret this to mean that respect involves taking care to appreciate learners for who they are and what they bring to a learning situation (e.g., appreciating their prior experiences) and taking care to not blame students for things they bring to the learning situation (e.g., not blaming students for lack of prior knowledge or for not being excited about the material). In terms of connectedness, Wlodkowski and Ginsberg emphasize issues of caring and responsiveness.

**Develop Attitude: Relevance and Autonomy**. The key idea of this principle is that having a positive attitude, orientation, or interest toward the material will contribute to intrinsic motivation to learn the material. Relevance and autonomy are then offered as two conditions that contribute to students having a positive attitude toward material. While understanding the relevance of the material may seem an obvious dimension of interest, what makes relevance interesting are the various dimensions along which something can be understood to be relevant: relevance to the profession may not be the same as relevance to the student; relevance to an
upcoming project may not be the same as relevance to projects far in the future. Consistent with their emphasis on intrinsic motivation and inclusiveness, Wlodkowski and Ginsberg are particularly interested in helping the students themselves see material as relevant, and they identify autonomy as a mechanism that can help students to see relevance. Letting students make choices in the context of learning, particularly choices related to the material, can help students create situations where the material is personally relevant.

*Enhance Meaning: Challenge and Engagement.* The ideas related to this principle are associated with creating conditions to help students engage in the types of actual activity that result in learning. Wlodkowski and Ginsberg explain the relationship between the terms as they intend them in this way: “Challenge can be understood as the *learning opportunity* itself while engagement can be understood as the *actions* students take.” In discussing these ideas, Wlodkowski and Ginsberg draw on the notion of the type of flow experiences that result when an “optimum” level of challenge (challenging enough but not overly challenging) is coupled with a positive disposition toward an activity. Providing learning tasks at the optimal level of difficulty is also considered an important component of motivating students.

*Engender Competence: Authenticity and Effectiveness.* Wlodkowski and Ginsberg round out their framework by focusing on aspects of assessment that can further contribute to students’ motivation to learn a particular topic. In particular, their emphasis is on how assessment can help learners see themselves as becoming effective in something that is of value to them. They further discuss this in terms of authenticity and effectiveness. Authentic assessment is something that has received a great deal of attention in the assessment literature. From their perspective, authentic assessment involves acknowledging the situations in which learning takes place, allowing learners to use what they naturally produce in those situations as evidence of their learning, and providing learners with multiple ways to demonstrate their understanding. In a sense, the idea is to create the best possible conditions for learners to demonstrate their growing understanding of the material. That, then, can be coupled with an emphasis on effectiveness, which they describe as, “the learners’ awareness of their command or accomplishment of something they find to be important in the process of learning or as an outcome of their learning.”

So how do the two cases introduced above embody the principles of inclusion, attitude, meaning, and competence? We discuss each case below.

**Link to Case 1: Class exercise**

In terms of *inclusion*, specifically respect and connectedness, the *squares activity* makes it possible for students who are entering with disparate levels of design experience to succeed and feel part of the class. Because the exercise both challenges experienced students and can be achieved by novice students, the exercise can be said to create a situation of respect. In other words, students are situated so that they do not feel blame for having too little or too much design experience. Further, because the students’ solutions *in toto* are subsequently used to discuss class concepts, conditions of connectedness are created. Moreover, because different solutions help to illustrate different points, every solution can be valued, further creating conditions of connectedness. It is interesting to think that the relative anonymity of this first assignment (student names did not appear with the solutions on the slides) creates conversation
and lays a path for activities to be more personal in the future. It is also interesting to note that while solutions were presented in an anonymous way, particularly clever solutions (e.g., solutions that did not seem at first to have been created according to the starting requirements) often elicited the class to ask who had created the solution and to have that person comment on his/her solution. Through this activity, students got to know each other and create connectedness conditions.

In terms of attitude, the specifications of the exercise speak to both autonomy and relevance, although in different ways. The potential for autonomy is essentially the same as with any design exercise—students are free to propose their solution and also to propose the basis for their solution (i.e., a quick solution, a solution that is possibly unlike one anyone else will produce). In terms of relevance, the task benefits from face validity—it is clearly a design activity in the context of a class on communication design. In addition, the lecture that is subsequently based on their solutions shows the relevance of their solutions to class activity, the potential relevance of their solutions to solving this problem, and even the relevance of contributing one solution in terms of generating ideas. Moreover, as the exercise proceeds, the students had a chance to see the relevance of the exercise toward class learning goals (e.g., learn about vector graphics) and class activities (e.g., learn to write a design rationale).

Turning to meaning, the specifications of the exercise speak to both challenge and engagement. As mentioned above, the exercise makes it possible for a novice designer to create a solution and the exercise provides an interesting design space for a more experienced designer (e.g., the experienced designer can try to find not just any solution, but a clever solution that no one else will consider). Part of this is the severe constraint put on the design space. Consider that even adding color to the squares that the students are asked to manipulate would add complexity to the design space. This significant constraining of the design space, coupled with the potential for complexity even for experienced designers, has potential to lead to a flow experience—an experience where the focus is thoroughly on the task at hand. The number of “wacky” and interesting solutions provided evidence that such a state was achieved.

So how does the exercise relate to competence, a concept that for Wlodkowski and Ginsberg is intrinsically tied to assessment, when the assessment in this activity was minimal (i.e., as long as students submitted a solution in the requisite technical format, they got credit)? In terms of authenticity, getting credit for producing a solution is actually a form of authenticity. In terms of effectiveness, the potential value was not in the formal efforts to support students’ understanding of their own effectiveness but in the informal opportunities that students had to see themselves relative to their peers and relative to goals of the class. One thing that could have supported the competence principle even further, and would have been relatively straightforward, would have been a discussion with students about what they “took away” from this exercise (this came up during conversation, but a targeted discussion question on this item did not occur). Such a conversation would have helped to externalize students’ personal insights so that other students could benefit from them.

Link to Case 2: Graduate multi-week project

In terms of inclusion, the design of the journal landscape project makes it possible for students to feel respected in terms of their interests, potential lack of interest, prior knowledge, and level
of expertise (as with the squares exercise, the journal landscape is do-able for a novice and a useful activity for a more advanced student). Opportunities for connectedness stem from the multiple points at which students are asked to share their ideas and to learn from each others’ ideas.

In terms of attitude, autonomy is an obvious dimension of this project. Most significantly, the students get to choose the journal they will address—in our significantly interdisciplinary department, this selection opportunity means that students can explore journals related to topics as varied as online help, children playing games, humanitarian relief, and informatics. In addition, the students get to choose the dimensions they will use to study the journal, the approach used to operationalize the dimensions, and their teammates. Further, while each choice is made available to them, they receive support in thinking through each choice. They also receive support in understanding the relevance of the task—a somewhat larger issue. In fact, part of the exercise is to help them (at least some of them) see journals and the content of journals as relevant to their professional activity. This issue of relevance, then, is discussed in class (i.e., such as by discussing the notion of a knowledge society and the importance of being able to critically evaluate new knowledge in a knowledge society). The issue of relevance is also brought out by celebrating instances where individual students find relevant information through this project. It is also interesting to note that the project, as defined, stays relevant since it is always focused on analyzing the most recent year of articles in a journal.

Turning to meaning, the specifications of the exercise speak to both challenge and engagement. In particular, the project is designed around things that students are asked to do, and then sufficient facilitation is provided so that students experience a reasonable, but not overwhelming, level of challenge. Concerning engagement, the idea is for students to start exploring the journal and be able to see patterns. The milestones are designed to help to manage the project over time and in terms of steps. In fact, the milestones have been chosen based on the types of difficulties that students encountered. The milestones also relate to challenge in that they provide students with the opportunity to ask questions (and, in relation to the issue of respect, we endeavor to take all questions seriously). Also, recently, in an effort to keep the students focused on this task of exploring and analyzing the journal, we developed and offered to the students a template for preparing their report.

As mentioned above, competence, for Wlodkowski and Ginsberg, is intrinsically tied to assessment. In this project, the assessment is based on two documents: the final report of the team’s analysis of the journal and individually written reflections in which students are asked to talk about what they learned from the project experience. The project report is linked to the overall issue of authenticity. In particular, the report is explained as something that they could share with peers, employers, and/or teammates interested in the journal that they analyzed. Further, as mentioned above, because the exercise is always current (they always analyze the most recent year), the students can know that their results are always new. In terms of effectiveness, the students clearly have the potential to look at their project report and think about what they have gained, and also to experience success at engaging with research. In addition, the required reflection is positioned as a place where they more explicitly articulate what they learned. As an educator, this information is quite valuable—this is where students share their insights such as becoming aware of journals, gaining confidence in being able to read journal articles, and gaining skills at asking more probing questions.
Occasioning the Emergence of Knowledge

Complexity theory, as applied to education, is concerned with the notion of a system that learns\(^2\). Complex systems are characterized by self organization, bottom up emergence, short-range relationships, nested structure, ambiguous boundaries, and the absence of equilibrium. Complexity theory is of interest in this age of rapid change because complex systems are capable of doing the unexpected. In terms of complexity, a basic tenet is that learning will emerge out of the interactions of many subcomponents or agents whose actions are constrained by similar, dynamic contexts, and that this emergence occurs not as a result of one agent in the system, but as a higher order phenomenon that occurs as agents interact with one another\(^4\). Complexity theory has the potential to help address challenges in education in general and in engineering education specifically\(^4,6\).

Instructional Principles

Davis and Sumara have proposed three principles useful for configuring complex learning systems. These principles, described below, have to do with the knowledge possessed by the agents interacting in the system and the types of interactions of these agents.

**Specialization**—*Living the tension of diversity and redundancy*. This principle is concerned with the amount of overlap and variation in the knowledge brought to a situation by the various agents (i.e., students) in the system. Redundancy in knowledge (e.g., redundancy in language, in experiences, in rules about how things work) is what permits the agents to be able to interact. Diversity of knowledge (i.e., when agents know things that other agents do not know) is what permits the agents through their interaction to respond to novel situations and to create innovative responses.

**Enabling constraints**—*Balancing coherence and randomness*. This principle is concerned with how agents interact and, in particular, what they are collectively doing. Coherence implies some unifying activity that the agents collectively address. This unifying activity provides the constraints alluded to in the principle. Yet, the activity also needs to allow for randomness in its direction in order to support the emergence of unexpected knowledge.

**Trans-level learning**—*Enabling neighbor interactions through decentralized control*. This principle is concerned with how agents and ideas interact in a complex system. According to Davis and Sumara, for a knowledge-producing complex system, it is primarily the interacting of ideas that will lead to new knowledge. However, they emphasize that ideas interact frequently through the interactions of the agents with the ideas (hence the emphasis on trans-level learning). The notion of neighbor interactions alludes to individual agents and their ideas spending a great deal of time interacting with each other, without going through a central channel. The notion of decentralized control represents the idea that the outcome of the learning is not forced toward a predetermined goal; but, rather, the direction of the learning emerges through the interactions.

**Link to Case 1: Class exercise**

Considering the class exercise (the squares activity) from the perspective of the *specialization principle*, we can make two observations. First, at a basic level, the configuration of most any class involves a situation of redundancy and diversity. Students in a class presumably share
things like certain amounts of prerequisite knowledge and some level of interest in the class. Regardless of such commonalities, the students are also certainly diverse in a variety of ways (e.g., different life experiences, different personalities). These aspects of redundancy and diversity set the stage for the variety of solutions that come out of the exercise (discussed below).

It is also possible to reflect on this principle in light of the conversation among the students upon seeing the lecture featuring their work. For example, in cases where students were asked to comment on their designs, they often elaborated on themselves. This necessarily resulted in members of the class having more knowledge about the ways in which the students were alike (redundancy) and different (diversity) from each other. Similarly, when the students were asked to think of a context in which a particular solution might be appropriate, they also tended to reveal information about themselves. For example, this happened when a student interested in mobile devices pointed to a particular solution as appropriate for such devices. Through these conversations, members of the class gained insight into the interests, personalities, skills, and experiences of the students across the class. This can be seen as creating potential for future activities.

The link to the enabling constraints principle is centrally through the design task itself. The nature of the task provided students with a great deal of coherence—everyone was engaged in the same activity. At the same time, the task, which sounded deceptively simple, was capable of resulting in a wide variety of solutions as the students demonstrated (hence the randomness).

The link to the trans-level learning principle has to do with the way in which the students’ design solutions were leveraged in the class. Recall that the solutions were integral to a presentation used in a subsequent lecture and discussion. In other words, students saw their solutions alongside other solutions and also had the opportunity to interact with each other in reference to their solutions—issues of neighbor interactions. Because the students’ solutions were all in response to the same set of constraints, they were positioned to better appreciate the different solutions. They were also positioned to use the different solutions to start to begin to create knowledge. At the same time, what they chose to notice was open, hence the decentralized control. For example, in discussing the solutions, the students began noticing how negative space was being used and ultimately starting to theorize negative space. Also, by attending to so many different examples, the students started paying attention to the direction in which the graphic was to be read (e.g., top to bottom, left to right, right to left). This observation led to conversations about cultural conventions and how they can or should be embodied in designs. Interestingly, this conversation also led to some people introducing themselves as bilingual or multilingual and sharing the other languages that they speak, an issue related back to the specialization principle.

Link to Case 2: Graduate multi-week project

Considering the graduate multi-week project from the perspective of the specialization principle, we can make observations in the same two categories as above. First, because the participants in the project were all involved in the same class, the situation involved a certain amount of diversity and redundancy. In this class, students, for example, could be assumed to share an interest in their graduate studies and certain background knowledge. At the same time, the students in this particular class were already known to be diverse relative to their disciplinary
background, the extent of their prior work experience, and their initial beliefs concerning the relevance of the course. As above, these aspects of redundancy and diversity set the stage for the variety of solutions that came out of the exercise (discussed below). Further, given the extent of sharing during the project activities, students necessarily learned a great deal about each other—setting the stage for future activity.

In this case, there are several links to the enabling constraints principle. First, the initial specification of the project involves two elements of redundancy: having the students choose a specific journal and having the students focus on five to seven dimensions as the basis for their analysis of the journal. Clearly, then, the randomness stems from students having different choices of journals and dimensions. Later in the project, the students were also given a template for writing up their report. The template creates coherence among the analyses, making it possible to better appreciate some of the randomness that ensues. Another link to the enabling constraint principle involves how reflection on learning was supported. In terms of coherence, each student was asked to write a short statement about what he/she had learned through the project. Given the different backgrounds of the students and their different choices in their project, the nature of the actual learning of the students has an element of randomness to it.

Finally, the connections to the trans-level learning principle have a great deal to do with how this activity was facilitated over time. In particular, the project process was set up to promote neighbor interactions. Recall that, in terms of process, students were sharing intermediate project elements (e.g., their journal choice, their dimension choices, their ideas for how to operationalize the dimensions, their almost finished work) on a regular basis. At each point, students were exposed to the range of ideas available at that point in the process, and they had the opportunity to think about patterns and to make meaning. For example, in learning more about a variety of journals during the sharing of their almost finished work, the students starting to talk in quite sophisticated ways about the publishing process for academic research and the nature of the discourse community for a particular journal. While these topics were among the topics to be covered in the course, the significance here is that these topics came out of the students’ conversation.

Discussion and Conclusions

In this paper, we introduced two sets of instructional principles that we found particularly useful in guiding our own teaching, and we provided illustrations of how these principles have been embodied in our teaching activities. It is interesting to note that these principles, which focus on issues of motivation and the emergence of knowledge, complement the types of principles that stem from a more cognitive focus (such as principles that focus on determining students’ prior knowledge in order to identify and correct naïve conceptions or misconceptions). In terms of the activities, while a reader could focus on trying the specific instructional activities we describe in this paper, we note that that was not our main point. In fact, we could have easily focused on other classroom exercises or multi-week projects that we have used in our teaching.

In general, a key message to be taken from our analysis is that the link to these principles lies not only in the starting activity, but also in how the instructional activity is facilitated over time. As suggested by the above accounts, the nature of how a project is facilitated is related to issues such as making something reasonably challenging (from the motivation framework), creating
conditions of coherence that permit useful randomness (from the complexity framework), and creating opportunities for neighbor interactions (from the complexity framework). While an insight that “it matters how we facilitate an activity” is certainly not news, these observations provide additional support for an educator trying to think through how to facilitate an instructional activity over time. These observations about the role of facilitation also provide a counter to a potential concern that providing such facilitation involves “dumbing down” the learning experience.

Turning to the frameworks themselves, we can make observations about the individual frameworks as well as their overlap. Concerning the motivation framework, an appeal of this framework is clearly the potential for all students to experience intrinsic motivation to learn. One thing we find interesting about this framework is the role of assessment—this is an area ripe for discussion. Concerning the complexity framework, it is worth noting that while instruction aligned with these principles is exciting, such alignment also requires a certain flexibility and adaptability on the part of the instructor, and it also may create interesting challenges for assessment. Finally, in terms of alignment between the two frameworks, it is useful to point out that the inclusion principle (via respect and connectedness) and the specialization principle (via redundancy and variability) have a great deal of overlap. It is also interesting to point out that local control is not unrelated to autonomy. These and other overlaps suggest that it might be interesting to pursue a hybrid framework.

We readily acknowledge a limitation of this work—that we have not taken the next step of providing evidence of the actual effects on student motivation or the comprehensive nature of knowledge that emerged in these two cases. While this was not a goal of the paper, it would certainly be interesting to have data on this issue. This remains for future work, as does the creation of examples where the principles described above are applied to other types of instruction (e.g., co-curricular activities such as coop, integrative activities such as portfolio construction).

Finally, we can note that these two sets of principles are quite relevant in our modern times. For example, given the national and international focus on diversity and helping under-represented populations succeed, the motivation-related principles that are focused on helping all students experience intrinsic motivation to learn are certainly of interest. Also, in lean times when educators are pressured to do more with less, the complexity-related principles that involve leveraging the power of large groups may provide a source of inspiration about new ways to proceed. Given this, we encourage readers to turn to the original sources of these principles to further explore the principles themselves and their application to teaching.

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