TEACHER AND STUDENT LEARNING IN CHEMISTRY: CONTRASTS AND CONTRADICTIONS

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Introduction

Classrooms at all levels of education are places which can only be understood ‘as a dynamic conceptual ecology’ (Roth et al, 2003. p. 114) where various social, cultural and intellectual forces interact in ways that are not always predictable. Many interactions are at best contrasting but in many cases are in fact contradictory. Meaningful learning in such a dynamic is premised on the assumption that students’ *worldviews* are congruent with those of the chemistry as it is taught. Without some shared understanding of the culture of classrooms both teachers and students live in quite different worlds.

Currently most teaching of chemistry is based on an objectivist view of knowing and learning and holds true that propositions can be tested through methodologies that transcend the subjective limitations of individuals to test such propositions and thereby ascertain absolute truths. Traditional chemistry teaching has subsequently focused on the direct transmission of these truths. Thus classroom interactions can be conceptualised as follows:

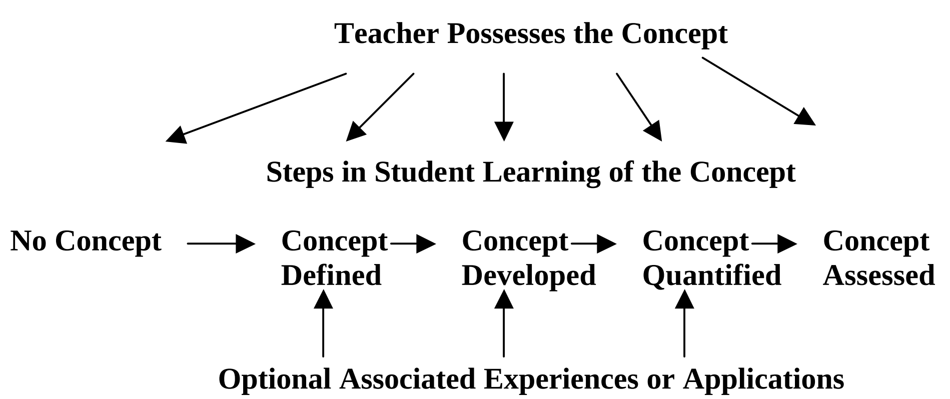
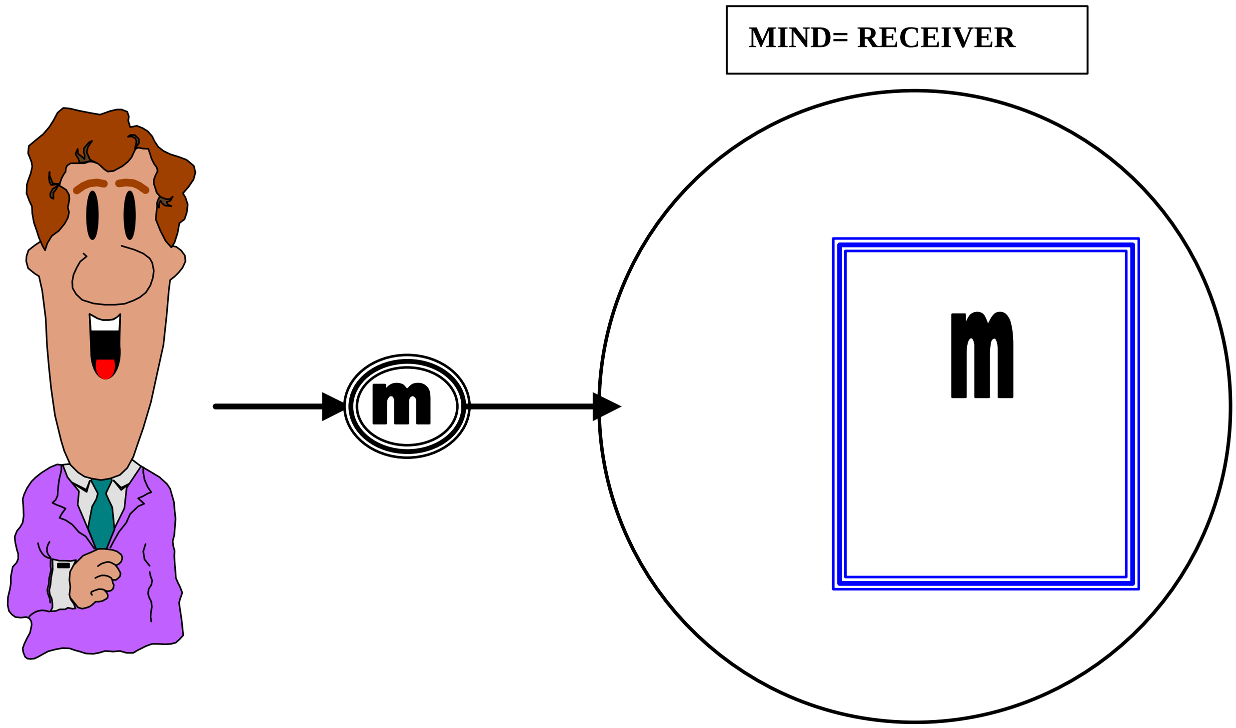


Figure 1. A model of teacher transmission of content in chemistry classrooms

Such a model of teaching has resulted in the application of scientific theory as an optional infrequent experience for students. When a real world context is introduced it is often done superficially through exercises and usually occurs at the end of an instructional sequence if time, interest or teacher knowledge permits.

From a learning perspective students are modeled as receivers.



The communicator is a transmitter. The communicator aims to make **m** as accurate, as clear, as exciting as possible.
The communicator is responsible only for the power of **m**. The aim is to find the perfect **m**.
The communicator is not responsible for the person's learning, which is an untheorised process in this model.

The person is modelled as a perfect receiver. If the person is sufficiently intelligent, attentive and open, then the **m** will be lodged in their minds with a perfect imprint.
This model is very hard on those people who cannot recall **m**. They are either: dumb, inattentive, or difficult.

Figure 1. Learner as Receiver: Communicator as Transmitter

The assumptions underpinning such an approach to learning are summarised in Table 1.

Table 1. Assumptions underpinning the "receiver" model of learning

WAYS PEOPLE LEARN	WAYS TO HELP PEOPLE LEARN MORE EFFECTIVELY	WHAT DETERMINES THE AMOUNT OF LEARNING
<u>Receivers</u> "Blank Slate" or "Tabula Rasa" (550 BC)	• Transmit A Clear Message • Tell, Command, Email, Direct **...** • Become A Better Presenter Of Information	• Clarity Of Message • Validity Of Message • Attentiveness • Intelligence • Motivation

To make this approach effective, teachers enact whole-class interactive and non-interactive activities because they allow the greatest coverage of content. This content is essentially the explanation of concepts and procedures for the calculation of problems followed by student independent activity that emphasises completion over comprehension. Students on the other hand emphasise exercise completion, getting the correct answers and getting higher grades (Roth et al. 2003; Goodrum et al, 2001). This approach to teaching and learning can be summarised as:

CONCEPT TO EXERCISE

A different emphasis in course design

A course design and its content are in the broadest sense a reflection of a hypothesis about learning - what is worth learning and how it should be learned and assessed, and as such reflects the deep-seated values and beliefs of the designers. In contrast to this objectivist view of knowing and learning (Tobin, 1990), the National Research Council (1996) has prompted a different vision for science education with:

Less emphasis on	**More emphasis on**
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter of disciplines	Learning subject matter in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science content	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts

Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned.

These desired emphases contain three major themes:

Concepts, Inquiry and Social Context.

The teaching and learning of chemistry within a framework encompassing these three themes will require a very different approach to coarse design.
The taught, learned and assessed curriculum will look very different from the transmission model outlined in Figure 1 above. A new emphasis in coarse design will require an approach which could be summarised as a:

CONTEXT TO CONCEPT

An example of how the relationship between social context (a group of related situations, phenomena, technical applications and social issues) and concepts could be envisaged is provided in Figure 2 below. In this particular framework two important themes in chemistry (from a discipline perspective) are emphasised. These themes are labeled structure and reactivity.

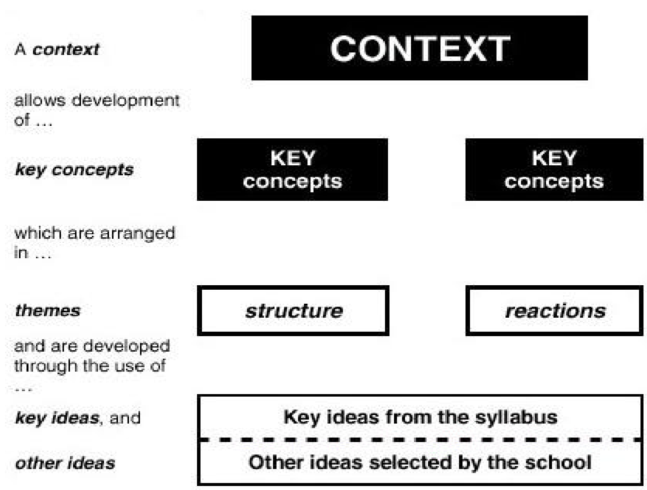


Figure 2. The relationship between context and concept in course design

This approach requires teachers to engage students in authentic real-world experiences of the context as the starting point for student learning (Anthony et al, 1998). In doing so the model requires that initially the context be elaborated by building up a concept map about the context. At the centre of this map is the context surrounded by a circle of issues, features or events associated with the context. Further out the associated science processes, models, topics, and science concepts are represented. Even further out is the source of information and skill building opportunities that are available to the class from within the institution or from the wider scientific community.

Associated with this radical change in pedagogy is a very different balance of student assessment instruments that are required to meet different outcomes. The balance is now very much in favour of student inquiry or investigations (Scientific and Non-Scientific) evolving out of focus questions generated from face-to-face interactions with the chosen contexts
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The following flowchart (Figure 3) outlines the major steps in the design of a topic commencing with the context being revealed, through to the finalisation of learning as evidenced in student presentations and reports.

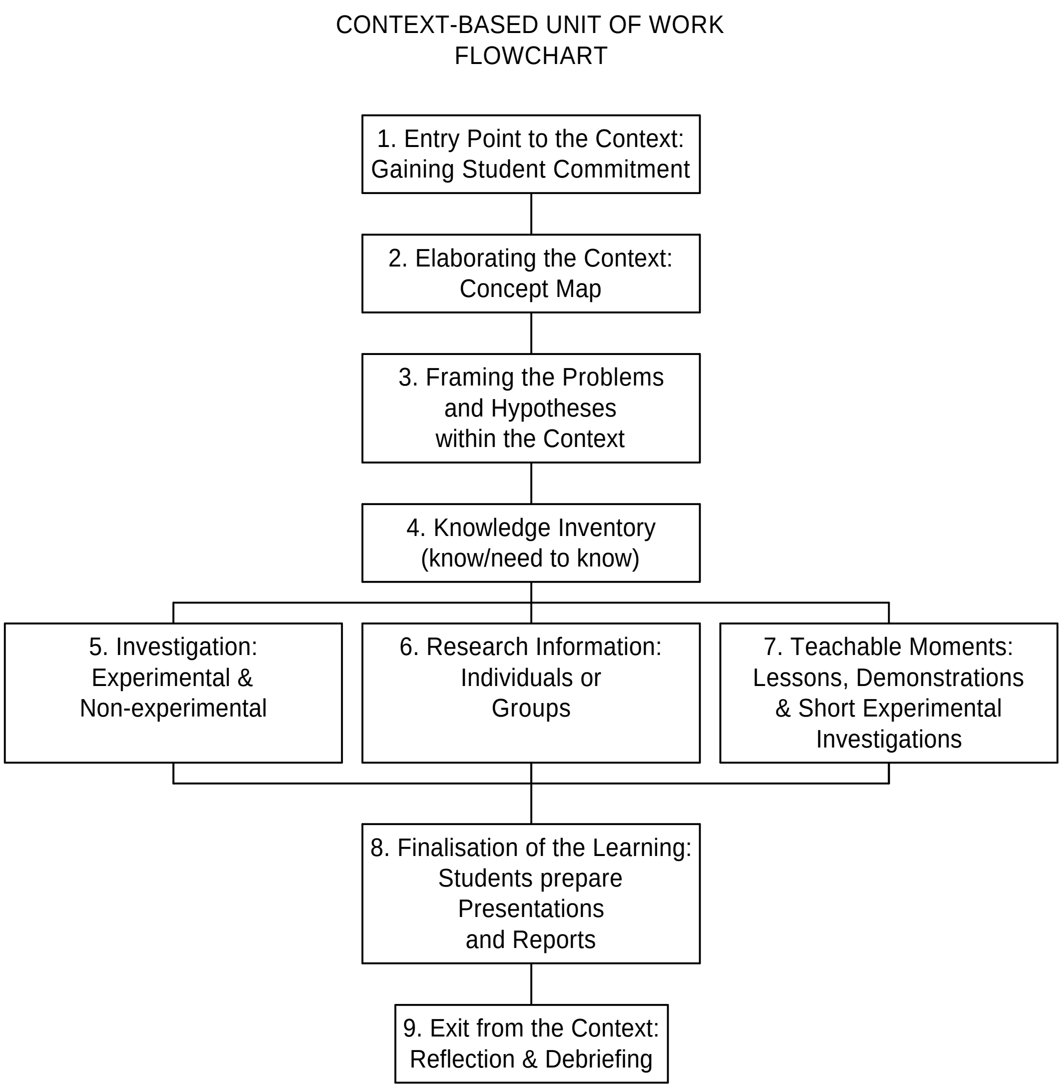


Figure 3. Context-based unit of work flowchart

Context-based design pedagogy

The starting point for the design of topics or units of work is the selection of appropriate contexts. The context and the concept map surrounding it are expected to lead to meaningful questions that will focus student investigations and other learning experiences. This decision is only constrained by interest and expertise, access to resources for investigations, the conceptual underpinning of the context, and the time required.

The design encourages teachers and students to develop an understanding of the key concepts on a 'need-to-know' basis. The context as initially revealed at the beginning of a unit remains central to the classroom processes and specific conceptual development becomes important when student uncertainty hinders further elucidation of meaningful knowledge and skills.

This learning design sequence represents a different approach to incorporate "inquiry" or "investigation" as central to what and how students are expected to learn. Comparison of the learning sequences diagrammed in Figures 1 & 3 soon reveals that a radical change in classroom pedagogy is required. However the challenge to *teach in context* and for students subsequently to *learn in context* is an emerging challenge for chemistry teachers (Lye et al, 2001; Whitelegg et al, 1999).

Learning in context builds upon two recognised principles of learning: student motivation and student prior knowledge and experience. Teaching in context requires strategies that enhance engagement and exploration by students of issues, ideas and concepts surrounding the context under investigation. Models of learning that accept students as "constructors" and "social constructors" are much more consistent with course goals that emphasize inquiry and social context as cornerstones of the design.

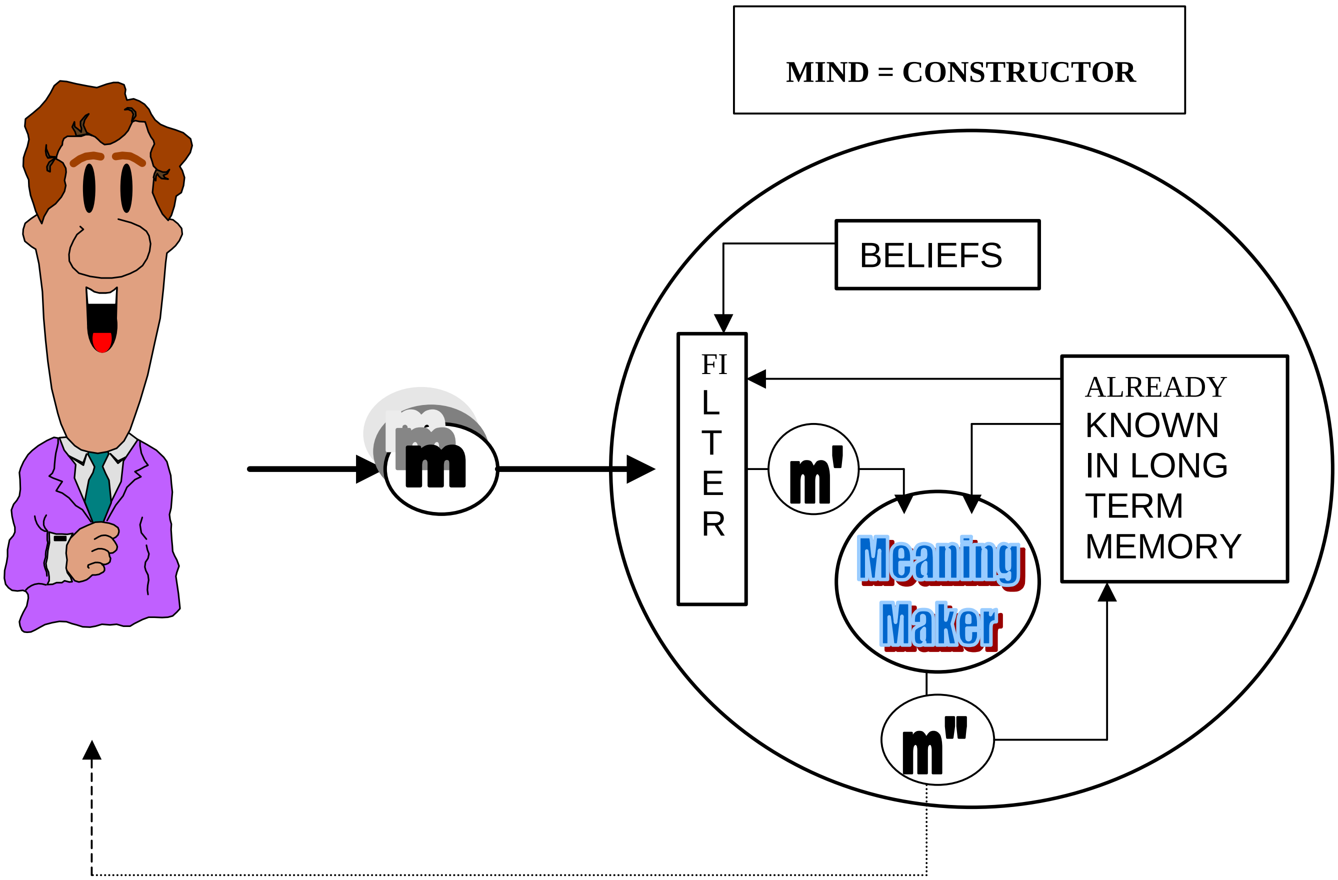
These attributes are illustrated in Table 2.

Table 2. Attributes of two models of learning

WAYS PEOPLE LEARN	WAYS TO HELP PEOPLE LEARN MORE EFFECTIVELY	WHAT DETERMINES THE AMOUNT OF LEARNING
Constructors (Piaget – 1900) (Ausubel – 1960)	• Transmit a clear message • Promote Interaction • Give feedback • Contest meanings • Know the learner	• What is already known • Quality of feedback • Quality of Interaction • Depth of Disagreements • Personal Activity • Beliefs
Social Constructors (Vygotsky – 1970)	• All the constructivist techniques + • Social Interaction • Scaffolding • Zone of Proximal Development • Social and Cultural Tools	• Trust in the Group • Interaction in the Group • Knowledge in the Group • Use of Cultural Tools • Beliefs

The relationships between the attributes in each of the models described above are illustrated in Figures 4 & 5 below.

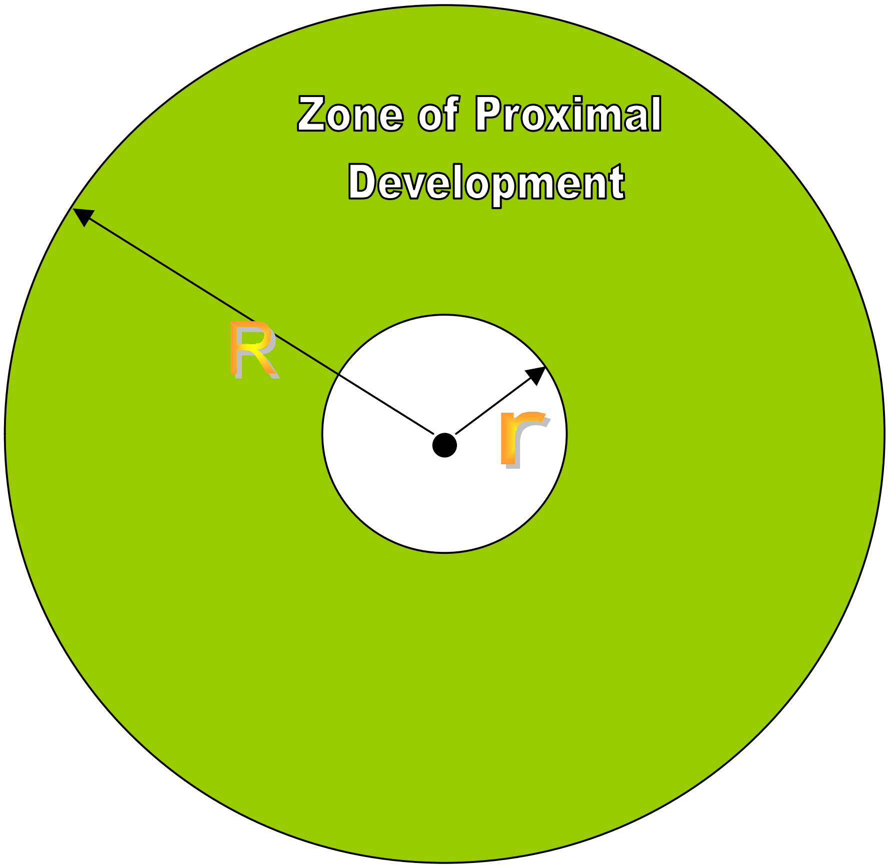
Figure 4: Learner as Constructor: Communicator as Facilitator of Meaning Making



Before the communication starts the communicator needs to know the person's beliefs and prior knowledge. During the process the communicator needs to get feedback on the **m''** that the person has constructed, to check it with **m**. Stephen Covey: "Seek first to understand, then to be understood." The communicator must have many versions of **m**, many ways of explaining concepts.

People needs to check the m'' **that they have constructed. The** m'' **is mainly determined by what the person already knows and believes.**

Figure 5: Learner as Social Constructor: Communicator As Scaffolder Of Group Interactions



Centre: represents what the person already knows. This point governs what the person is able to learn.

Circle with radius r: Represents what the person is able to learn on their own with the help of cultural tools: books, www, …

Annulus between circles with radii r and R: is termed the Zone of Proximal Development (ZPD): Represents what a person can learn because they are a member of a social group who share knowledge and use cultural tools to learn.

To promote learning: make R as large as possible: To achieve this, form the group, help them to trust, appreciate, share, give feedback, check their understandings, speak to think, have open minds to each other, with the communicator scaffolding all the learning.

In conclusion

Our understanding of curriculum design, teaching, learning and assessment have been considerably enhanced over the past 20 years. Yet in many ways our students are required to learn in ways which are more consistent with our knowledge base one hundred years ago. . Transmission style teaching and learning have been with us forever yet we continue to persevere with practices that have severe limitations in achieving more desirable outcomes. The National Research Council (1996) document has provided a framework for change – a change that is much more in keeping with what is espoused by prestigious professional societies and chemical educators as necessary if the teaching and learning of chemistry is to move into new millennium.

Professional practice such as teaching has always been challenging when “radical” change is proposed. In this paper the contradictions about current practice, curriculum designs and learning models have been highlighted. These new emphases require radical change in pedagogy to accompany the new emphases in course content with new outcomes. However what is being proposed does not really represent “new” knowledge about course design or content in an educational sense. It is just very different from what is being practised in a majority of classrooms and therefore represents radical change from current practice. If chemistry as a discipline had ignored all the relevant research on the structure of materials then the Bohr model of the atom would be as far as we would have come in our representation of matter.

Renewing the educational enterprise will only come about through changing human behaviour and in this case it will mean substantial change for both teachers and students. People’s worldviews and their learned experience will need to be challenged and re-developed if practice in chemistry education is to be enhanced.

Students, like their teachers, will need to learn in a socially constructivist manner about how to learn within this new paradigm for chemistry education. In designing for these opportunities teachers will also need to demonstrate their commitment to social constructivist designs. These designs emphasise the rich and complex learning that can be achieved by reflecting together on personal experiences in a shared course.

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