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Reconciling beliefs and practices in teaching and learning

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Abstract Current teaching and learning methods reveal marked differences between how students approach learning and how instructors approach teaching. Little attention has been paid to understanding these differences and their implications for designing successful learning environments. The purpose of the paper is to introduce a framework for understanding and reconciling perspectives on teaching and learning success. First, we examine perspectives on learning success. Next, we compare and contrast beliefs and practices associated with teaching and learning. Finally, we introduce a model for reconciling teaching and learning beliefs and practices, and discuss implications for future research and practice.

Keywords Learning success · Teaching success · Reconciliation

In classroom settings, learning is a shared enterprise involving instructors and students. However, in practice, teaching structures and activities can vary from the expectations, strategies and activities of learners. Instructors may be unaware of how their students perceive their teaching. In some cases, fundamentally different epistemological beliefs may exist related to instructor–student roles (Perlman & McCann, 1998). An instructor may, for example, consider inquiry

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into and reflection about student misconceptions to be paramount. A student, in contrast, may be cognitively compliant (McCaslin & Good, 1992), expect an instructor to specify core factual information, and provide correct answers. Conversely, a student may wish to engage in topical debate while the instructor may favor the efficiencies attained via group lecture. Taken separately, instructor and student expectations and beliefs may be considered reasonable and appropriate. Together, however, misalignments are often evident among the expectations, beliefs, and practices of instructors and students (Maclellan & Soden, 2003). While successful instructors and students recognize the value of, and employ complementary methods, some neither fail to recognize nor deploy complementary approaches (Chandler, Chiarella, & Auria, 1988; Georgiou, Christou, & Stavrindes, 2002; Graham, 1991; Gredler, 1992; Peterson, 1990).

Multiple measures of learning success exist, ranging from student satisfaction (Giuliano & Sullivan, 2004), to grade point average (Schommer, 1993), to completion of course requirements (Driscoll, 1999), to integrated conceptual understanding (Songer & Linn, 1991), to the ability to argue and reason (Qian & Alvermann, 1995). Among successful students, knowledge, and beliefs about knowledge, tend to evolve concurrently (Duit & Treagust, 2003). Among less successful students, however, knowledge may lack personal meaning, be superficial, and be wrought with misconceptions (Chi, 2005). Therefore, to promote understanding of knowledge and beliefs among such students, additional, deliberate effort may be needed.

It is important to examine the co-dependencies of a shared teaching–learning enterprise to help instructors understand student needs, identify teaching strategies that help facilitate learning, and determine how and when to accommodate them. Concurrently, it is important to examine how students adapt and accommodate their learning strategies based on awareness of the beliefs and practices of the instructor. In effect, each might be able to better identify when and how to reconcile their beliefs and strategies to align their efforts and promote learning success.

The purpose of the paper is to introduce a framework for understanding and reconciling instructor and student perspectives on teaching and learning success. We first introduce conceptual change learning as a lens through which teaching–learning alignment can be examined, and compare and contrast associated beliefs and practices. Finally, we introduce a model for reconciling teaching and learning beliefs and practices, and discuss implications for research and practice. Since considerable variation exists across domains, age, educational levels, and learning requirements, it is not our intent to present either the model or the examples as absolute. Rather, we describe research studies that epitomize the constructs and principles of both conceptual change and the model.

Conceptual change

According to Bereiter (2002), current educational practices tend to emphasize *direct explanation* (i.e., explaining things as clearly as possible to the learner)

as well as *process or performance perspectives* (i.e., knowledge as ''reference material in a mental filing cabinet'' [p. 118] that is ''pulled'' when needed). Bereiter and others have argued for a shift in focus to students' beliefs about and connections with conceptual artifacts.

Conceptual change refers to the learning process of restructuring pre-instructional understanding to develop new interpretations and acquire new knowledge (Posner, Strike, Hewson, & Gertzog, 1982). Conceptual change, therefore, involves changes in both knowledge and beliefs about knowledge (Duit & Treagust, 2003). Most conceptual change models emphasize how students approach learning, and encourage instructors and students to make their conceptions about to-be-learned content explicit from the outset (Hewson, Beeth & Thorley, 1998). Table 1 summarizes four widely studied conceptual change perspectives: theoretical, revisionist, teaching, and process.

Posner et al.'s (1982) initial work focused principally on cognitive ecology. They synthesized Kuhn's (1970) conception of scientific revolution and Piaget's (1977) theory of developmental psychology, and suggested that learning is a product of the interaction between what students are taught and their prior knowledge. Four conditions for conceptual change were theorized: (1) dissatisfaction with existing conceptions; (2) new, intelligible conceptions; (3) initial plausibility of the new conceptions; and (4) potential for new approaches to teaching and learning. In Posner et al.'s study of student

Table 1 Summary of conceptual change models

The model	Authors	Characteristics	
		Strengths	Weaknesses
Theory of conceptual change	Posner et al. (1982)	Identified key cognition factors contributing to conceptual change in students' learning	Lack of focus on the role of instructors in students' conceptual change learning process
Revisionist theory of conceptual change	Strike & Posner (1992)	Added affective factors (e.g., motivation) as contributing factors to students' conceptual change learning process	Still lack of focus on the role of instructors in students' conceptual change learning process
Teaching for conceptual change	Hewson et al. (1998)	Recognized the significant role of the instructor's teaching in students' conceptual change learning process	Lack of attention to the dynamic relationship between teaching and learning
Processes of change	Merenluoto and Lehtinen (2004)	Recognized the different paths that students may take based on their different cognitive, metacognitive, and motivational sensitivity to the task	Lack of attention to the impact of the instructor's teaching on the paths that students may take

understanding of special relativity, dissatisfaction was evident when a college student recognized a personal misconception (i.e., that Newtonian mechanics' calculation of the lifetime of a meson was shorter than what was observed experimentally). This student subsequently recognized that special relativity's prediction (the new conception) was consistent with experimental findings, thus making it intelligible. Posner et al. (1982) suggested that successful accommodation occurs when dissatisfaction was followed by recognition of intelligibility, strengthening their belief in the plausibility and fruitfulness of the new conception (i.e., Einstein's special relativity). They also suggested that prior knowledge about the subject (i.e., Newtonian physics), epistemic beliefs (i.e., value of experimental evidence), plausibility of the alternative (special relativity theory), and the interaction among factors contributed to successful accommodation.

While cognitive factors are clearly important to conceptual change, some have concluded that purely cognitive connections are unlikely to occur without affective influences (e.g., Garner, 1990; Pintrich, Marx, & Boyle, 1993). Reflecting on criticisms of the strict cognitive perspective in their earlier work, Strike and Posner (1992) revised their model to expand the *conceptual ecology* metaphor to include anomalies, analogies, and metaphors that might scaffold new information, exemplars and images, past experiences, metaphysical beliefs about the world, and knowledge in other fields. They also suggested that conceptions and misconceptions interact with, rather than operate independent from, other components of their model, noting that differing conceptions can exist to varying degrees and via alternative representations. Finally, Strike and Posner advanced a development-interactionist interpretation of conceptual ecology, emphasizing dynamic and developmental patterns of mutual influence between and among model components. From this perspective, interactions exist among epistemological views of science, confidence in the ability to learn science (i.e., learning attitude), attitudes towards science, and success in physics learning.

Building on Posner et al.'s (1982) conceptual change theory, Hewson et al. (1998) suggested that three additional factors influence conceptual change learning in conjunction with metacognitive factors: ideas, status, and justification. Ideas refer to both teacher and student conceptions about the subject under study. Hewson et al.'s (1998) *Teaching for Conceptual Change* model suggested that teachers made explicit both their and their students' ideas during instruction via pre-instructional quizzes (Minstrell, 1982) and small-group posters (Children's Learning in Science Project, 1987). Status refers to the degree to which a student believes an idea is useful. Accordingly, Hewson et al. advocated teaching practices that help to raise or lower the status of ideas. Raising the status of an idea increases emphasis, which may increase opportunities for students to accept it. In contrast, lowering an idea's status may reduce the likelihood that students accept it. By introducing and experimenting with the special relativity theory, for example, the instructor raised its status, thus increasing the likelihood that students would accept the new theory (Posner et al., 1982). Finally, justification involves linking knowledge,

beliefs, and values, and focuses on the interactions within a student's conceptual ecology. In Posner et al.'s study, the student referenced prior knowledge together with his beliefs in the importance of experimentally-generated empirical evidence. Learning involved raising or lowering the status of a studied conception within the student's conceptual ecology.

Merenluoto and Lehtinen (2004) extended Posner et al.'s (1982) work, positing several paths that a student might go through during the conceptual change learning experience. The *Processes of Change* Model is a systemic model of learning success where students encounter tasks and materials that induce conceptual change. They hypothesized that cognitive, metacognitive, and motivational sensitivity influence how students perceive a task. Cognitive sensitivity refers to the relationship between prior knowledge and the cognitive demands of the task. In Merenluoto and Lehtinen's study of secondary school students, students were tested on three dimensions of rational and natural numbers: formal hierarchy and facts of real numbers, the density of the number line, and concepts of the limit and continuity of a function. Students were asked to estimate the certainty of their answers. Cognitive sensitivity was low when students reported slight over-confidence for familiar tasks and low certainty on difficult tasks. In contrast, students with high cognitive sensitivity reported lower certainty estimates on difficult tasks than on familiar tasks, indicating greater novelty in their thinking and the radical nature of experienced change.

Metacognitive sensitivity refers to meta-conceptual awareness of knowledge. According to Merenluoto and Lehtinen (2004), metacognitive strategies are prerequisite to understanding conflicting notions: Students with strong meta-conceptual awareness of their prior knowledge (metacognitive sensitivity) related to density and the number line were already able to address the conflict between rational and natural numbers, whereas students whose sensitivity to the density and number line concepts was low failed to revise their perspectives despite the teaching intervention.

Motivational sensitivity refers to the tendency to seek novel or surprising features during learning. When appropriately motivated, learners are generally better able to identify novel features in a learning task, demonstrating awareness of cognitive conflict, and promoting conceptual change. In Patrick and Yoon's (2004) investigation of 8th graders' science learning, one student's motivation to understand global warming led her to ask follow-up questions, such as whether sulfur dioxide was a greenhouse gas, which she was unable to answer herself. She both identified questions and persisted until she obtained a satisfactory answer.

However, strong motivational beliefs can also hinder conceptual change. Another performance-oriented student was motivated to speak often and be perceived as an authority among peers. When his authority was threatened, he appeared concerned that his credibility would be undermined. On one occasion, for example, the teacher pointed out a contradiction in his reasoning—that carbon dioxide was a greenhouse gas but sulfur dioxide was not. The student disregarded the teacher's comments and explanation of the contradiction, and repeated his initial argument.

Reconsidering beliefs and practices

While research and theory have emphasized the roles of students and instructors, they have focused primarily on the influence of conceptual change activities on student learning. For example, Hewson and Hewson (2003) found that instructional strategies integrating students' prior knowledge and principles of conceptual change had significant positive effect on students' acquisition of scientific conceptions. Such guidelines may be inconsistent with the teaching values and approaches of instructors. Though considered critical to learning success, more exploration is needed to distill the implications of conceptual change theories for both teaching and learning have been reported (Hampton & Roy, 2002; Pintrich et al., 1993).

Classroom obstacles to conceptual change have also been documented. Given the same instruction in the same classroom, some students demonstrate conceptual change learning while others do not (Abd-El-Khalick &Akerson, 2004). Similarly, evidence of conceptual change varies under different situations and circumstances (Duit & Treagust, 2003). While researchers have underscored the influence of factors such as prior knowledge, the introduction of new or alternative knowledge, the use of metacognitive learning strategies, and motivation (Strike & Posner, 1992), few have examined the interdependence among conceptual change factors such as epistemic beliefs, teaching, and learning. Epistemic beliefs refer to an individual's beliefs ''about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs'' (Hofer, 2002, p. 4). Little effort has focused on the influence of associated beliefs and assumptions on teaching, factors that influence student expectations about learning, and their joint influence in typical learning environments. In this section, we present teaching and learning models and describe the influence of epistemic beliefs on the teaching practices of instructors and the learning practices of students.

Learning

Several factors influence student learning. Students rely on prior knowledge and experience to inquire about existing learning phenomena and to seek new ones (Posner et al., 1982). In Posner et al.'s (1982) study, students referred to their prior knowledge about Newtonian physics when encountering a new theory. By reasoning through alternative relationships, triggered by the conflict between existing and new knowledge, a student may retain, modify, or replace their existing conceptions. Since motivation influences the inclination to learn as well as the activation and transfer of knowledge (Garner, 1990), students need to seek new conceptual understandings (Pintrich et al., 1993).

The *Processes of Change* model underscores the importance of relating existing knowledge with new knowledge. A student who is unable to create a relevant connection between to-be-learned information (i.e., the new learning phenomenon) and existing knowledge might avoid engaging in activities, thus

minimizing the prospect of conceptual change. In their number study, Merenluoto and Lehtinen (2004) found that students who identified numbers as whole numbers, fractions, and decimal numbers only by superficial features demonstrated insufficient prior knowledge to identify, classify, and construct problems in the domain of rational and natural numbers. Thus, these students provided low certainty estimations for their answers. As a consequence, their engagement with the alternative concept (i.e., rational number concept) was mainly avoidance. Alternatively, students with sufficient prior knowledge expressed lower certainty estimates in rational number tasks as compared to more familiar natural number tasks. Using their metacognitive strategies and motivational beliefs, they typically reconstructed their understanding of rational number concepts.

Teaching

Content and pedagogy are closely intertwined; how and what instructors teach influences how and what students learn (Bereiter, 2002). Instructors have the capacity to perceive and respond to students, as well as to design instruction to promote successful student learning. Hewson et al.'s (1998) *Teaching for Conceptual Change* model suggests that instructors strategically elevate or diminish the status of ideas through classroom activities, thereby causing students to confront ideas, issues and perspectives that support as well as compete with existing conceptions. One way to accomplish this is to challenge students' ideas about a chosen topic. Hennessey (1991) described a 6th grade classroom application where the instructor required students to state their ideas, present ''attractions'' and limitations of their ideas, question whether they were consistent, accept that they might need to change and apply the ideas of intelligibility and fruitfulness to their ideas.

Beliefs and experiences also influence how instructors teach and students learn. Ertmer (2005), upon analyzing the influence of K-12 teachers' beliefs on their inclination to integrate technology into their instruction, concluded: ''When considering ways to change teacher practice, the literature...suggests that it is impossible to overestimate the influence of teachers' beliefs'' (p. 36). Hewson et al. (1998) suggested that metacognitive processes are inherent to conceptual change. When given alternative ideas related to a phenomenon, students comment on, compare and contrast those conceptions—metacognitive activities that influence the value and strength of knowledge.

Similarly, Jimenez-Aleixandre (1992) studied a teacher who organized students into small groups, and asked them to discuss individual pretest answers on evolutionary theories and to consider contradictory examples. The teacher subsequently facilitated a whole-class discussion, focusing on inconsistencies between students' answers and canonical views of science. By initially defending and subsequently revising initial conceptions, students developed richer conceptual understandings and improved their ability to warrant their claims.

Modeling interplay between teaching & learning: the reconciliation model

One way to help unsuccessful students in the conceptual change learning process is by reconciling the interplay between teaching and learning. Reconciliation is the process of examining and aligning teaching and learning expectations and beliefs. Successful instructors often reconcile by recognizing differences between their underlying teaching beliefs and practices and student learning practices. Conversely, successful students reconcile by recognizing differences between their individual learning beliefs and practices and instructor's teaching practices. Several factors influence the likelihood and success of reconciliation: epistemic beliefs, students' and instructor's prior experiences, motivation, and students' metacognitive learning strategies, and instructors' teaching strategies.

Without sufficient prior knowledge, for example, students may lack requisite background to engage effectively in advanced instructional activities. Alternatively, they may lack the motivation or determination to invest the needed effort. In some cases, however, student beliefs, expectations, and strategies differ from those of the instructor. Unsuccessful students may resist efforts to learn and withdraw from the instruction, minimizing conceptual change and attributing failure to instructor shortcomings (Chandler et al., 1988; Peterson, 1990). In other instances, students may simply give up, attributing failure to their own shortcomings and inadequacies (Graham, 1991; Gredler, 1992).

Likewise, instructors' expectations, beliefs, and practices often differ from those of students (Poole & DeSanctis, 2003). Instructors may lack adequate knowledge or experience needed to teach specific topics effectively, fail to recognize student dissonance, or lack willingness to modify their teaching. Rather than reflecting and adapting to reconcile differences, teaching activities may proceed as initially planned, independent of evidence of student learning, thus not fully facilitating students' conceptual change process. In such cases, instructors might attribute failed student performance to lack of prior knowledge and motivation, blaming them for failing to engage in their teaching activities (Georgiou et al., 2002) rather than to the misalignment of expectations or their teaching. Ideally, instructors and students mutually adapt their respective activities to reconcile dissonance.

Assumptions of the reconciliation model

Beliefs about the locus of knowledge influence teaching and learning expectancie

Several scholars have suggested that classroom teaching practices and learning approaches are strongly associated with instructors' and students' beliefs about teaching and learning (e.g., Hofer & Pintrich, 1997; Kagan, 1992). Posner et al. (1982) suggested that existing beliefs about learning and to-be-learned subjects established conditions for student conceptual change

learning. According to Schommer's (1990, 1994) framework, epistemic beliefs range from naïve to sophisticated: naïve beliefs indicate that knowledge is perceived as simple and a direct reflection of reality with no need for justification, while sophisticated beliefs indicate that knowledge must be understood contextually and must be open to reevaluation. Chan and Elliott (2004) reported that students with naïve beliefs about knowledge tend to characterize knowledge as resting ''in'' authorities (usually the instructor). Accordingly, a student might expect the ''instructor as expert'' to explicitly organize and convey his or her knowledge, such as by directed lectures and explicit study guides. Conversely, instructors' beliefs about teaching and learning influence how well they facilitate students' conceptual change learning experiences. When an instructor believes that knowledge is complex and can be constructed by the learner (Schommer, 1994), he/she might be expected to provide the students with opportunities to explore the to-be-learned subject, such as by project-based or inquiry-oriented learning approaches.

The ability to reconcile is both teachable and learnable

According to several authorities, formal education influences epistemological development, increases competency to evaluate information critically, and resolves competing knowledge claims (see for example, Hofer, 2004; Kuhn, 1991). Researchers suggest that reflective judgments about epistemic beliefs evolve incrementally. King and Kitchener (2004), for example, noted that doctoral students scored higher on reflective judgment tests than college students, who in turn scored higher than high school students. Reflective judgment reflects the maturity level of one's epistemological beliefs. As individuals become increasingly sophisticated in their understanding of epistemic beliefs through exposure to diverse instructor beliefs and practices, they become more skilled in reconciling their beliefs with those of others (Schommer, 1994; Schommer-Aikins, 2004). Yet, refinements may or may not be engendered through everyday teaching and learning, but rather may require an educational environment that both challenges and supports growth (King & Kitchener, 2004).

Reconciliation requires both the ability to detect teaching–learning misalignment and willingness to adapt strategies accordingly

Epistemic beliefs influence both how instructors teach and students learn (Hofer, 2004), as well as their willingness to reconcile (Schommer, 1994). Nussbaum and Bendixen (2003) suggested that personality traits may influence student engagement in social-academic activities, such as debates or idea exchanges. In their study of 238 undergraduates (primarily preservice teachers), students who were more assertive tended to approach arguments whereas students with warmth personality traits tended to avoid them. The results suggest that students with assertive personality traits may be less inclined to reconcile their ideas than those with empathetic traits. Compelling

evidence may be needed to persuade assertive students to consider alternative conceptions, and to encourage all students to share their beliefs. Recognition may also help to catalyze a reexamination of existing beliefs and practices (Brindley & Laframboise, 2002), thus make possible efforts to resolve a misalignment. When students fail to recognize misalignment between their learning and the instructor's teaching, they tend to reify rather than modify existing conceptions (Duit, Roth, Komorek, & Wilbers, 2001).

Willingness to reconcile is influenced by several factors, including individual beliefs and personality traits. When instructors believe that knowledge resides in authorities (i.e., the instructor in the classroom), it is unlikely s/he would change practices even according to situational demands. Consequently, a student may fail to learn novel ideas or skills such as new ways to write or technology applications (Schommer-Aikins, 2004). In contrast, when instructors believe that all knowledge is negotiable, they might inadvertently legitimize simplistic student understanding. Students may fail to recognize conventions or canonical points of view, thus reinforcing, rather than challenging, naïve conceptions (Schommer-Aikins, 2004).

Recognizing and adapting also requires that students possess sufficient metacognitive awareness and skills and differentiate learning strategies (Merenluoto & Lehtinen, 2004). Bereiter and Scardamalia (1993), for example, suggested that expertise influences one's orientation: experts tend to perceive in broad, underlying principles, whereas novices attend to superficial features (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Farr, 1988). Instructors, therefore, may need to scaffold novices' detection and adaptation, such as by explicitly pointing out the cognitive dissonance and highlighting underlying general principles.

The initiative for reconciling varies according to situational demands, task factors, and community practices

Circumstances influence who might initiate reconciliation efforts and how those efforts might be enacted. Some domain topics and skills, such as microsurgery and dental practices, require that experts model standard conventions and procedures. In many instances, students must acquire specifically-prescribed knowledge and practices of a community as modeled by the instructor (Hung, 1999). In contrast, areas such as general liberal arts curriculum tend to value diversity of interpretation and perspectives, as narrow understanding of their own beliefs and behavior may hinder students from becoming autonomous (Kember, 2001). Still other subjects (e.g., introductory physics, chemistry, and biology) may be taught by instructors who have the expertise, knowledge, and skills to make their domain of study interesting and accessible to non-majors, as one way to raise scientific literacy among the general population (see National Science Education Standards, 1996).

The reconciliation model

In the following, we provide examples where the reconciliation model can be applied to identify and address potentially unproductive or ineffective teaching and learning processes. The model identifies relationships between and among student and instructor reconciliation processes, but does not attempt to account for all possible variations or to prescribe specific solutions; rather, our purpose is to frame the model's features and components within representative applications.

As illustrated in Fig. 1, student epistemic beliefs exert an initial influence on the learning process (Posner et al., 1982; Schommer, 1990). King and Kitchener (1994) viewed the development of epistemological beliefs as a progression through three phases. In phase I, students demonstrate pre-reflective thinking, believing that right and wrong answers exist and that only authorities know the correct answers. In phase II, students engage in quasi-reflective thinking, beginning to question previously held assumptions and recognizing that authorities can provide incorrect or biased perspectives. In phase III, students demonstrate reflective thinking, and begin to understand knowledge in relationship to the context in which it was generated.

Consistent with theory and research on conceptual change, as students engage in new learning activities, they attempt to reference related prior knowledge and experience (Posner et al., 1982). When new activities are unfamiliar or conflict with prior knowledge or existing beliefs, cognitive dissonance occurs. Festinger (1957) characterized cognitive dissonance as the discomfort experienced with a discrepancy between what a person already knows or believes, and new information or interpretations. Once students experience cognitive dissonance, they may pursue different paths depending on how (or if) other factors in the learning environment are considered. For example, if motivated to learn, the student may adapt their conceptions and learning strategies and gain new conceptual understanding (Pintrich & De Groot, 1990). In contrast, lack of motivation may prove detrimental from the outset of the learning process. Yet, motivation alone does not ensure learning success; for students to become successful learners, they must identify and utilize strategies appropriate to given task demands (Merenluoto & Lehtinen, 2004). Given motivation to learn and the ability to deploy effective learning strategies, students are better able to reflect and adapt their approach, are more likely to persist, ultimately becoming successful learners.

Likewise, instructors' epistemic beliefs underlie their everyday classroom teaching practices (Flores, 2001; Freeman & Porter, 1989), and influence student–instructor interactions and instructional planning (Gibson & Dembo, 1984). Those beliefs are influenced by several factors, including assumptions about students, learning, instructional materials, and instructional design (Kagan, 1992). Building upon these underlying beliefs and informed by prior teaching experience, the instructor designs and implements activities in their learning environment (Flores, 2001; Hannafin & Hill, 2002), monitoring the teaching process and seeking evidence of student engagement.

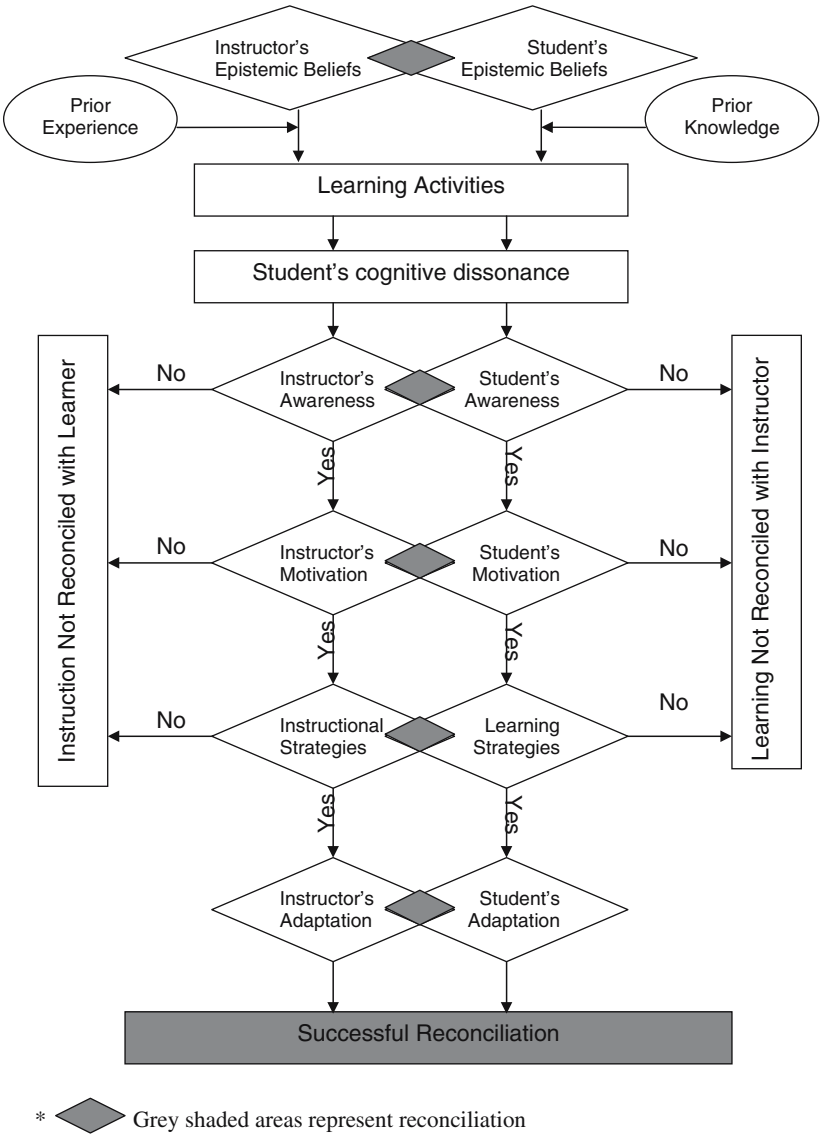

Fig. 1 Modeling epistemological reconciliation

Once the instructor introduces new or alternative concepts, students may experience cognitive dissonance. To the extent the instructor is aware of student cognitive dissonance and is motivated to adapt instructional strategies, opportunities to modify teaching activities as well as to reflect on teaching practices improve, as does the potential to influence students' conceptual understanding. For example, Hewson and Hewson (2003) demonstrated that instructors improved students' conceptual understanding of science by

explicitly referencing their prior knowledge and scientific conceptions and applying conceptual change principles (e.g., differentiating existing conceptions into more clearly defined but related conceptions).

Modeling interplay between teaching and learning

While the preceding depicts teaching and learning processes independently, neither occurs in isolation in typical classroom contexts. The beliefs and practices underlying teaching and learning are inextricably linked (Hewson et al., 1998). Unsuccessful students often fail to recognize dissonance- or conflict-inducing events, lacking the requisite prior knowledge or motivation needed to succeed. Conversely, unsuccessful instructors often fail to recognize, reflect, and adapt when students do not learn. To the extent the instructor recognizes the dissonance, it becomes increasingly possible to resolve the lack of correspondence. Several factors influence how well instructors and students identify or adapt teaching and learning activities, including prior knowledge, beliefs about teaching and learning, motivation, and cognitive strategies.

Prior knowledge

Hewson and Hewson (2003) examined the effect of 9th graders' prior knowledge and conceptual change strategies on learning about mass, volume, and density. The experimental strategy explicitly addressed students' preconceptions while the control strategy did not. The experimental strategy first established a relevant mental set, addressed alternative conceptions using differentiation and exchange strategies, and then related the new information to existing conceptions. Students were then asked to indicate whether a given statement was correct, incorrect or was not understandable (e.g., Wood floats because it has no mass) and to elaborate their responses. Despite varied initial conceptions about the world, which were often ill-formed, hazy, and inappropriate, students in the experimental conditions developed richer scientific understandings than control students, as evident in both their posttest scores and explanations. Prior knowledge, therefore, may help to guide students' assessments of to-be-learned knowledge and teaching activities. Alternatively, when to-be-learned concepts are inconsistent with prior knowledge, cognitive dissonance may signal students' need to reconcile personal understandings with new knowledge or examine how teaching activities do (or do not) help to address dissonance.

Beliefs

According to Hashweh (1996), instructors holding constructivist beliefs may be more apt to detect alternative conceptions and induce conceptual change, compared to instructors espousing empiricist beliefs. Likewise, students who view instructors as respected authorities are more likely to refine their beliefs

and be open to new ideas and conceptions (Pajares, 1992), that is, more likely to reconcile their learning practices with the instructor's teaching. Further, students who have more sophisticated beliefs (i.e., where knowledge is contextualized) are more likely to accept perspectives that conflict with their prior knowledge (Mason, 2003), thus are more likely to reconcile their learning

Motivation

Student motivation toward conceptual understanding is manifest by reflecting on existing knowledge (Garner, 1990), trying different learning strategies (e.g., seeking different resources) (Pintrich & De Groot, 1990), and being willing to reconcile (Stark, Mandl, Gruber, & Renkl, 2002). For instructors, motivation to reconcile influences the inclination to facilitate the student's adaptation/reflection process. For students and instructors, the stronger the motivation, the greater the possibility for reconciling their respective practices.

Cognitive strategies

In Jacobson and Lehrer's (2000) geometry study, 4th graders' performed best when teachers understood students' thinking and reasoning about geometry, and modified their strategies accordingly. Therefore, a dependent relationship exists between instructor and student strategies and the potential for reconciliation: To the extent the student or the instructor recognizes which strategies best align with each other's needs, the likelihood of success increases.

Types of reconciliation

Unilateral reconciliation

Unilateral reconciliation involves efforts by either the teacher or the student to resolve misalignment. In Maclellan and Soden's (2003) study of undergraduate teacher–education students, some students indicated that ''justification is about showing that one's own beliefs are right and that this is achieved by simply stating them'' (p. 9). Maclellan and Soden suggested that such students prefer direct approaches, where the instructor explicitly directs performance rather than approaches where students are encouraged to interpret and generate unique meaning. Alternatively, students might formalize personal beliefs and reconcile differences between these beliefs and the instructor's teaching practices (e.g., studying in groups to increase discourse, varying perspectives, participating in topical discussions, and preparing compare-contrast written assessments). In effect, accommodation to teaching activities, and implicitly the instructor's epistemic beliefs and practices, is made unilaterally by the student.

In contrast, instructors who engage students in open, free-form discussions might re-focus their efforts to approximate the situational demands of professional licensing exams in order to reconcile their practice with the

immediate needs of students. King and Kitchener (1994) suggested that the instructor could make ''what counts'' to students an explicit course feature, focusing on concepts perceived as difficult by students. This practice may also help students to become aware of different perspectives on issues; evidence offered in substantiation could be open to evaluation. In each case, accommodations in practice—teaching or learning—are made by one to reconcile with the beliefs, needs, or practices of the other.

Mutual reconciliation

Mutual reconciliation involves negotiation and accommodation by both instructors and students. Each enters the learning environment with beliefs and expectations, which are enacted in their respective teaching–learning activities (Chan & Elliott, 2004). When dissonance is experienced by students, it becomes evident to the instructor either explicitly (e.g., student statements) (Maclellan & Soden, 2003) or tacitly (e.g., lack of engagement). In mutual reconciliation, students may strive to identify the goals and beliefs that underlie the teaching activities to determine possible adaptations in their learning strategies (e.g., self-study). The instructor may strive to identify the nature of student confusion as well as their goals and expectations to consider alternative teaching activities (e.g., study guides). The potential for reconciling beliefs and practices, and for successful learning, increases as each accommodates and adapts based on improved understanding and recognition of the shared enterprise.

Misalignment and alignment of beliefs

Two examples from the same study illustrate the assumptions and factors associated with the reconciliation model. Song and Hill (2004) examined the interaction between a university instructor's teaching and student learning in a graduate level course [see Rieber (2000) for detailed information about the course]. Consistent with constructionist *epistemological beliefs* (Kafai & Resnick, 1996; Papert, 1991), the instructor *designed* the course to allow the students to learn web page development by building web pages appropriate to individual project requirements—a personally meaningful artifact for students. The students were expected to: (1) choose a project per their own interests; (2) choose a development tool to learn; and (3) develop the Web page for their projects using the tools they chose to learn.

An instance of misalignment

Mindy, an experienced schoolteacher who returned to graduate school for professional development, struggled with the constructionist-inspired course activities, course expectations, and activities. During previous formal K-16 education (*prior knowledge/experience*), she excelled where the instructor's goals and teaching activities focused on specific information and skills,

typically in the form of a lecture. Mindy *preferred* instructor-directed learning (*beliefs*), stating, ''I have always been led by hand...Tell me to do this and I will do it.'' She experienced *dissonance* due in part to conflicting *beliefs* with the instructor who promoted student-directed learning. Limited *prior knowledge* about web page development as well as a lack of *experience* with self-directed learning may have heightened the challenge of the learning experience. Since she worked full-time, she was not sufficiently *motivated* to devote extra time to access the instructor and peers, but rather relied mainly on web page development books, software, e-mail and telephone contact with peers and the instructor.

The consequence of misalignment was somewhat predictable. Mindy's learning approach and experiences, based on her *beliefs* and her *educational experiences*, were not aligned with the course design, which was influenced by the instructor's beliefs and prior teaching experiences. In this situation, the locus of responsibility for reconciliation rested with both the instructor and the learner (Mindy). However, when Mindy encountered problems, she neither took initiative to make her difficulties visible to the instructor nor adapted her learning strategies. The instructor, unable to detect her cognitive dissonance, failed to adapt his teaching activities. Ultimately, Mindy attributed problems to a mismatch between teaching activities and her learning style (see Graham, 1991; Gredler, 1992), and made little effort (*lack of motivation*) to resolve the dissonance. The experience served to reinforce her belief that she was incapable of learning on her own, thus ineffective in using technology in student-centered learning environments.

An instance of alignment

Randy, in contrast, returned to school to extend his skills. Randy's prior formal education experiences, like Mindy's, were largely directed in nature, where teaching goals and activities focused on delivering specific information and skills. Shortly after class started, Randy expressed confusion about the unfamiliar constructivist approach employed by the instructor, and voiced his concerns to the instructor. In addition to talking to Randy about his personal concerns, the instructor convened a session during which he reviewed the principles associated with the constructivist approach, explaining how the constructivism-inspired course activities, course expectations, and instructional activities were aligned with his beliefs about how learning occurs.

By mid-semester, Randy reported that while the amount and type of decisions he needed to make were challenging, he enjoyed the freedom of choosing. Like Mindy, Randy experienced initial *dissonance* due to initial conflicting *beliefs* with those of the instructor. However, consistent with previous research findings (Maclellan & Soden, 2003), he was able to reconcile his differences and align his practices with student-directed learning approaches. In addition, Randy was able to draw upon his own prior web development experiences as well as the experiences and input of his peers and the instructor.

Randy took several steps to reconcile the initial misalignment. First, he initiated contact with the instructor, asking about the approach and questioning what was occurring. The instructor, *aware of* Randy's cognitive dissonance, was able to clarify his beliefs and why he designed the course strategies and activities. Randy also adapted both his expectations and his learning strategies, utilizing peers and others to guide his learning. Further, unlike Mindy, Randy attempted (*motivation*) to resolve the dissonance and to enact different learning strategies. The experience served to reinforce the belief that he was capable of learning on his own and using technological tools in student-centered learning environments.

Implications for design and practice

The reconciliation model helps to clarify the extent to which teaching and learning beliefs and practices are, or can be, shared. While at some level this appears self-evident, efforts to reconcile beliefs and practices have rarely been explicitly applied. Several considerations may improve the reconciliation process.

Make epistemic beliefs explicit

Whether reconciled unilaterally or mutually, instructors and students can benefit by making their beliefs explicit to each other. However, since significant differences may exist between espoused and enacted beliefs, and between self-reported and actual practices (Hofer, 2002; Murray & Macdonald, 1997), simply stating one's epistemological beliefs may be insufficient.

One practical option is to make visible the assumptions upon which courses are designed and developed (Hannafin & Hill, 2002). Instructors can engage in critical reflection activities to examine and reflect on their beliefs, such as through conversing with peers or colleagues (Flores, 2001) or explicitly describing teaching philosophies to the students at the beginning of the course. By overtly initiating otherwise tacit information, the instructor can clarify the biases and expectations underlying course design and student performance.

Another implication for teaching, especially for diverse student populations, is to provide opportunities for students to make *their* beliefs explicit (Hewson et al., 1998; Wilson, Ludwig-Hardman, Thornam, & Dunlap, 2004). Louca, Elby, Hammer, and Kager (2004) suggested that observations and interviews were helpful in understanding students' beliefs about knowledge and learning, their learning behaviors, and their approaches to learning tasks in different contexts. Students, in turn, can become increasingly proactive by explicitly articulating their learning philosophies to the instructor and making potential misalignments explicit.

Identify disconnections between expectations

The instructor's expectations guide course design, teaching, and evaluation (Flores, 2001; Hannafin, Hannafin, Land, & Oliver, 1997), while students' expectations influence how they plan for and approach learning (Hofer, 2002; Hofer & Pintrich, 1997). Understanding the relationships between expectations can both help to clarify underlying beliefs and expectations and identify appropriate adaptations (Jacobson & Lehrer, 2000; Maclellan & Soden, 2003).

Through grounded practice, instructors can deliberately align their underlying foundations and assumptions, linking the methods and approaches accordingly (Land & Hannafin, 2000). Understanding the correspondence between underlying beliefs and practices empowers instructors and students—both independently and mutually. Instructors can help students to understand the value assigned to various course units, activities, and requirements and encourage students to express their beliefs to heighten awareness of potential misalignments from the outset.

Assess capability to reconcile

Understanding epistemic beliefs and recognizing disconnections between respective expectations and practices forms the basis for reconciliation, but does not guarantee that it will occur. Since instructors have historically assumed positions of power in formal learning environments (Friere, 1970, 1993), they may fail to recognize or be unwilling to reconcile misalignment. Some students have been forced to reconcile unilaterally to accommodate the instructor's teaching practice (Hung, 1999). It is important, therefore, to acknowledge the mutual importance of reconciliation to effective teaching and learning, and to develop both the inclinations and strategies.

Instructors may adapt their teaching activities by collecting students' opinions on their learning experiences to guide teaching practices during both particular courses and courses to be taught to similar populations in the future (Jimenez-Aleixandre, 1992). Instructors may also share with students their own beliefs about the teaching and learning process so that students can use the information to guide their own understanding of why the learning process is enabled in certain ways, adjusting as needed to reconcile with their own beliefs. Research is needed to identify alternative reconciliation strategies for instructors and students and to refine our knowledge base.

Optimize interplay

As Bruner (1996) noted, education both reflects the beliefs and practices of a given culture and provides opportunities for students to reflect on their personal epistemic beliefs. While it is possible to achieve learning or teaching success via the efforts of either the instructor or student, mutual reconciliation may optimize success beyond what is possible unilaterally. Mutual reconciliation requires a shared commitment to optimizing the synergy between

teaching and learning rather than to preserve or maintain individual practices. More research is needed to explore strategies to optimize the interplay between teaching and learning in order to improve students' learning success.

The intrinsic value of personal beliefs must be acknowledged if they are to be negotiated and ultimately shared. In Hung's (1998) study, a novice student appropriated another student's approach after observing successful mathematical problem solving. While this study focused on student peer collaboration, Hung described parallels to teacher–student (i.e., expert–novice) collaboration. Instructors and students need to both make their respective beliefs explicit to one another and recognize the value of each other's beliefs. Discussing and reflecting on epistemological beliefs may help to optimize the interplay between teaching and learning activities.

Clarify reconciliation criteria

While contextual and domain factors influence both how and when reconciliation efforts are undertaken, reconciliation can inadvertently promote undesired outcomes. For example, students may become cognitively compliant by matching their knowledge and perspectives with instructor's expectations (McCaslin & Good, 1992). In cases where inadequate coaching and scaffolding are provided by the instructor, students may be unsure of the validity of their individually constructed meaning (Song, 2005).

It is also important to note that reconciliation is neither required for teaching and learning to be effective, nor can or should all cognitive dissonance be reconciled via mutual adaptation. In some cases, the instructor has sophisticated expertise and techniques, which must be learned and performed with precision and accuracy. In Chin, Bell, Munby, and Hutchinson's (2004) study of cooperative education in a dental practice, students were required to memorize precise instrument sterilization procedures, along with the coding systems used to designate which teeth and surfaces were worked on. The conventions were standardized within the dental community, so while the instructor could be sensitive to *how* they were learned, the student ultimately needed to learn and adhere to the conventions. Conversely, where liberal arts or general survey knowledge is emphasized, the educational goal may be to make domain knowledge more accessible and interesting to diverse students. Instructors can adapt teaching activities to make ideas more relevant to students with different background, needs, and interests.

Adapt instructional activities

The reconciliation framework implies the importance of instructors adapting their instructional practices to help facilitate students' conceptual change learning processes. Understanding students' existing knowledge on the to-be-taught subject and beliefs about learning and teaching in general helps raise the instructor's awareness of potential cognitive dissonance that the students might experience in their conceptual change learning experiences.

Several instructional strategies can help instructors achieve this goal including concept mapping, role-playing, argumentation, and discussion (Prather, 2005; Rebich & Gautier, 2005). For example, by asking students to sketch a picture of an atom and label each part of the atom, the instructor could gain an understanding of students' pre-existing conceptions about the nature of radioactivity (Prather, 2005). In Rebich and Gautier's (2005) study on the role of concept mapping to reveal undergraduate students' pre-existing knowledge and conceptions about global climate change, they found it to be a valuable assessment tool that provided information about student knowledge structures that enabled identification of commonly help misconceptions. They also suggested that instructors could use this information revealed by the concept mapping tool to guide the design and refinement of the learning environment.

Having gained some understanding of students' existing knowledge and beliefs, we suggest that instructors adopt a grounded design approach to design their instruction. A grounded design approach (Hannafin et al., 1997) emphasizes the importance of the alignment between the instructor's epistemological beliefs and his/her practice in the design of the learning environment. It appears that the better the alignment, the more effective the learning environment. Once instruction has started, instructors could utilize several strategies to help raise their awareness of students' cognitive dissonance so that they could better facilitate students' conceptual change learning processes. As Driver (1983) noted, students must be provided with opportunities to think and talk about the implications and possible explanations of what they were observing in order to promote conceptual change. This can be achieved by asking students to write journals to record and reflect on their learning experiences in the class: helpful and challenging activities and strategies. Other strategies may include involving students in open discussions and/or debates related to the subject area. Through discussions and argumentation, students could validate or adjust their claimed beliefs, thus helping the instructor to raise his/her awareness of students' conceptions and beliefs (Yip, 2001).

Examine the impact of reconciliation

Considerable research has been conducted to build an understanding of students' conceptual change learning processes. Still, research is needed to examine the circumstances under which unilateral, mutual, or no reconciliation is needed or effective, strategies used to reconcile teaching and learning practices, and the influence of reconciliation on assessments of teaching–learning enactments and beliefs. Evidence suggests, for example, that unilateral accommodation to instructor expectations may improve student performances on specific target learning outcomes, but also engender compliant cognition. Likewise, research indicates that both instructors and students are often unable to adequately articulate their beliefs and expectations, complicating efforts to reconcile. In addition, research is needed to examine systematically the impact of reconciliation on teaching practice and student

learning. Though recognition of a need or desire to adapt may be requisite to adapting teaching or learning strategies, the literature is replete with examples of significant differences between intended (as well as espoused) and enacted practices. It is important to examine actual changes in instructor and student practices associated with reconciliation.

Conclusion

Current teaching and learning models help provide useful lenses through which to examine everyday practices. In their most basic form, they help to specify, analyze, interpret, and understand a range of factors that influence the independent forces acting on students and instructors within learning environments.

The reconciliation model extends, and to some extent changes, how we conceptualize the relationships between, and interactions among, instructors and students. The term, reconciliation, acknowledges the shared nature of the teaching–learning enterprise, and the importance of addressing instructor–student co-dependence. Using the model, we recognize multiple ways in which reconciliation occurs (as well as when it does not), describe alternatives for mutual accommodation, and identify implications for practice.

Several issues, such as the timing and techniques of reconciliation and ways to measure personal epistemic beliefs, remain both with respect to the roles of instructors and students in promoting successful learning in general, and as conceptualized in the model in particular. While the model simplifies the myriad of considerations and factors, it provides a useful framework to guide closer, and more detailed, study of student and instructor roles.

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