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Interdisciplinary Learning: Process and Outcomes

Lana Ivanitskaya, Deborah Clark, George Montgomery, and Ronald Primeau

ABSTRACT: Interdisciplinary learning is characterized by the integration of multidisciplinary knowledge across a central program theme or focus. With repeated exposure to interdisciplinary thought, learners develop more advanced epistemological beliefs, enhanced critical thinking ability and metacognitive skills, and an understanding of the relations among perspectives derived from different disciplines. Our adaptation of Biggs and Collis' (1982) Structure of the Observed Learning Outcome illustrates the stages of interdisciplinary knowledge integration and explains corresponding patterns of learners' intellectual functioning, from acquisition of single-subject information to transfer of interdisciplinary knowledge to other topics, issues, or problems.

KEY WORDS: interdisciplinary learning; critical thinking; metacognition; epistemology.

Central Michigan University's (CMU) interdisciplinary Master of Arts in Humanities program brings together adult students from a variety of professional disciplines to explore literature, history, music, art, philosophy, religion, and film from the unifying perspective of a central core issue. Topics of focus include problems of identity, race, gender and ethnicity, and dialogues between Ancients, Moderns, and Postmoderns. To provide an effective and supportive community for adult learning, each student completes the program as a member of a stable cohort. Over 20 months, a cohort of about 25 students completes ten courses together. In the process, each student contributes unique

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insights from his or her discipline and learns in similar ways from others.

Program course work includes topics from classical rhetoric to modern art, science fiction in film to the contemplative traditions in world literature. Students visit with cast and crew of opera productions, tour art galleries, and collaborate on first–hand historical research. A sampling of present offerings includes "Vienna and Twentieth Century Austrian Literature," "Asian Civilization: Tradition and Modern Transformation," "The Philosophy of Self," "Seminar in American Individualism," and "Religious Dimensions of African American Music from the Spirituals to Gospel."

Historically, CMU has applied the same student assessment strategies across its interdisciplinary and traditional single-subject courses: regular examinations, written papers, course assignments, and end-of-course student surveys. But as part of an ongoing internal effort to improve the rigor and descriptive value of program assessments, the director and faculty of the M.A. in Humanities program recently gathered with researchers from CMU's Center for Research on Adult Learning (CRAL) to develop a deeper understanding of the interdisciplinary aspects of the program. Based on observations of the quality of students' class discussion and integrative approaches to learning material, faculty shared a concern that conventional assessments insufficiently addressed the breadth of students' learning outcomes, e.g., enhanced critical thinking, applied metacognition, and greater sensitivity to cross-disciplinary connections.

To develop a deeper understanding of interdisciplinary learning outcomes in CMU's M.A. in Humanities program, the authors conducted a comprehensive review of the literature on interdisciplinary studies so that we could articulate how interdisciplinary learning differs from more traditional learning focused on single-subject topics. While the delineations separating disciplinary and interdisciplinary learning are not discrete, efforts to devise useful assessment strategies require some foundational agreement about the predominant intellectual outcomes characteristic of each approach. Discipline-specific study may be particularly valuable for novice learners and those seeking specialization. Several researchers, however, have suggested that traditional studies may be too fragmented and limited in scope to meet students' educational goals (e.g., Baloche, Hynes, & Berger, 1996; Humphreys, Post & Ellis, 1981; Jacobs, 1989). Discipline-specific approaches frequently fail to demonstrate how a particular discipline interfaces with another (Baloche, et. al., 1996). As a consequence, students presented

with information in an isolated manner tend to acquire knowledge in disparate categories (Humphreys, et al., 1981) and may fail to perceive, or even question, the overlapping values or questions raised by different disciplines.

Alternatively, interdisciplinary learning should create knowledge that is more holistic than knowledge built in discipline-specific studies. Interdisciplinary approaches, while arguably less effective than traditional approaches for building the depth of single-subject knowledge, emphasize higher-order thinking (e.g., analyzing, applying, generalizing) and seek meaningful connections between and among disciplines. Lake (1994) has argued that learners in interdisciplinary programs are guided beyond simpler forms of knowledge acquisition to a deeper assimilation of cross-disciplinary concepts. For example, students in an interdisciplinary program might complete a critical analysis of the connections between the visual arts, musical expression, cinema, poetry, and philosophical and political thought characteristic of a particular era.

In this article, we discuss perspectives on the ways interdisciplinary learning is conceptualized, the expected outcomes of integrated education, and explanations for the ways learners tend to integrate knowledge in interdisciplinary programs.

Perspectives on Interdisciplinary Learning

Multidisciplinary learning "refers to the involvement of several different professional areas, though not necessarily in an integrated manner" (Shafritz, Koeppe, & Soper, 1988). By contrast, Rowntree (1982) defines the interdisciplinary approach as "one in which two or more disciplines are brought together, preferably in such a way that the disciplines interact with one another and have some effect on one another's perspectives" (p. 135).

For example, CMU's M.A. in Humanities program brings together professional teachers of literature, history, music, and art to study their mutual fields, identify where their fields of expertise overlap, and share their individual and group perspectives. In this program, as in other interdisciplinary programs, students are asked to apply analyses and knowledge derived from several disciplines to a core issue, problem, or experience. One of the interdisciplinary courses offered, a literature course on the poetry of Paul Laurence Dunbar, synthesizes the methodologies and language of several disciplines to explore the world

of work through the poet's revealing insights. Dunbar's verse is set to music and re-examined through the study of African masks, thereby providing students with interpretive strategies not available from any single perspective or isolated discipline.

There are several convincing arguments for curriculum integration. As summarized by Jacobs (1989), curriculum design insufficiently addresses the explosive growth of domain-specific knowledge and the need for relevance. As the body of accumulated information grows within a discipline, instructors employing a more traditional teaching approach may be hampered by an inability to cover primary subject matter with a high degree of specificity. Interdisciplinary learning circumvents this obstacle by shifting the programmatic focus from memorization of facts to focus on a central theme, application of knowledge relative to this theme, and reflection on the thinking process. As a case in point, interdisciplinary study of a historical period may be less concerned with facts and dates than with how people of the time asked questions or how they expressed their values in artistic forms or through cultural symbols.

As reviewed by Schommer (1994) students attaining higher level beliefs about the source, certainty, and organization of knowledge (epistemological beliefs) are better prepared to contend with complex knowledge domains that lack structure. In turn, development of higher level epistemological beliefs relates to the pedagogical strategies characteristic of interdisciplinary programs: more personal construction of knowledge, emphasis on coping with difficult tasks and the search for multiple solutions, focus on the evolving connections among ideas, and interpretation and application of knowledge across several contexts (Schommer, 1994). Though interdisciplinary study may not equally serve all educational purposes, the intention of promoting complex thinking skills may be facilitated when curricula "balance a focus on thinking process with a focus on learning specific content" (Baxter Magolda, 1992, p. 286).

Unlike curricula that unwittingly encourage memorization of discrete bits of specialized information, interdisciplinary education readily facilitates the development of *structural knowledge*: an understanding of higher-order relationships and organizing principles (Goldsmith & Johnson, 1990). *Declarative knowledge* (factual information) and *procedural knowledge* (process-based information), used for problem solving or step-by-step task completion (Anderson, 1982), form the foundation for the acquisition of structural knowledge. For example, students analyzing relationships between members of a dominant culture and those defined as "other" will need declarative knowledge of a culture and events within it to understand its points of conflict; but they will

rely on procedural knowledge of various disciplines to promote critical probing. The structural knowledge essential to integrated programs promotes learners' ability to assess critically the relationships among multidisciplinary perspectives and evokes a deeper cognitive analysis of the core theme of the program.

Interdisciplinary approaches also lead to complex, internalized organization of knowledge. Goldsmith & Kraiger (1996) defined this organization of information as a "knowledge structure"—an internalized framework of all the related perspectives, concepts, ideas, and methods of inquiry making up the knowledge domain and giving it meaning. Knowledge structures are known by several labels: "schemas," "mental models," or "conceptual frameworks;" but despite differences in terminology these constructs all represent a central tenet of cognitive science. The tenet is that the organization of knowledge is at least as important as the quantity of knowledge accrued in helping the individual to determine when and how a set of declarative facts applies to a particular situation (Dorsey, Campbell, Foster, & Miles, 1999). While knowledge structures are not exclusively interdisciplinary phenomena, the capacity to create meaningful connections across the knowledge domain is significantly facilitated by the introduction of interdisciplinary perspectives. For instance, students who are aware of opera, jazz, novels, and sermons are likely to envision the meaningful patterns connecting them and extend these insights into newly encountered events and ideas.

By focusing on an issue or core theme, interdisciplinary approaches encourage students to perceive the connections between seemingly unrelated domains, thereby facilitating a personalized process of organizing knowledge. For example, students in an interdisciplinary humanities course might be encouraged to draw perceptual connections between fields such as ethics, drama, or even the popular cultural dimensions of commercial design. Dressel (1958) suggested that interdisciplinary programs provide students with a sense of how multidisciplinary knowledge can be organized and offered a point of initiation for an individual's own process of discipline integration. As students assimilate newly integrated concepts with prior knowledge and experience, they create increasingly complex connections between declarative facts that may ultimately predict the retrievability of knowledge (Acton, Johnson, & Goldsmith, 1994).

Assessment techniques targeted at mapping knowledge structures in novices and experts suggest that expert problem solving coincides with a more coherent organization of information within the knowledge

domain (Dorsey, Campbell, Foster, & Miles, 1999). As a consequence, when highly skilled persons are confronted with a practical problem, they tend to recall larger blocks of integrated knowledge rather than smaller subsets of information (Wyman & Randel, 1998).

In sum, higher levels of structural knowledge are associated with improved problem-solving and knowledge transfer skills and increased memory, retention, and comprehension of information learned. To a higher degree than traditional, single topic approaches, interdisciplinary learning fosters a problem-focused integration of information consistent with more complex knowledge structures.

Learning Outcomes

Several authors have described the anticipated learning outcomes of the interdisciplinary approach (see Table 1). These outcomes span the development or enhancement of cognitive skills (e.g., improved thinking and learning skills) and may encompass more subtle outcomes, such as

Table I
Predicted Outcomes of Interdisciplinary Programs

Author	Outcome
Ackerman (1989)	Flexible thinking
	Ability to generate analogies and metaphors
	Understanding of the strengths and limitations of disciplines
	Ability to assess value to knowledge gained
Ackerman & Perkins (1989)	Enhanced thinking and learning skills
	Improved higher-order cognitive skills
	Improved content retention
	Capacity for proactive and autonomous thinking skills
	Ability to devise connections between seemingly dissimilar contexts
Field, Lee, & Field (1994)	Ability to tolerate ambiguity or paradox
	Sensitivity to the ethical dimensions of issues
	Enlarged perspectives and horizons
	Ability to synthesize or integrate
	Enhanced creativity, original insights or unconventional thinking
	Enhanced critical thinking
	Capacity to perceive a balance between subjective and objective thinking
	Humility, sensitivity to bias, and empowerment
	Ability to demythologize experts

modified perspectives and attitudes (e.g., enhanced sensitivity to the ethical dimensions of issues).

A growing number of cognitive theorists agree that "the relation between knowledge acquisition and performance in many domains requires not just a set of declarative facts, but a framework or a set of connections that leads to an understanding of when and how a set of facts applies in a given situation" (Dorsey, et al., 1999, p. 32). Convergence of disciplines on one relevant theme promotes intellectual maturation through the analysis, comparison, and contrast of perspectives contributed by each discipline.

Interdisciplinary competence is highly dependent on building connections between theories, approaches, methods of inquiry, concepts, and paradigms, i.e., interpretive tools through which students derive a frame of reference for exploration of a programmatic theme. For example, the interactions between the individual and societal norms can be explored in historical and political dimensions; analyzed philosophically; and expressed in literature, film, or visual art. Mastery of interpretive tools enables learners to compare the aggregate of all perspectives derived from contributing disciplines.

As learners attain mastery in interdisciplinary studies, they use interpretive tools to combine and integrate information into a complex interdisciplinary knowledge structure focused on the program's theme. This knowledge structure reflects many central facets of the program: its integrated theories, essential concepts, effective modes of inquiry, and primary paradigms. Causes in critical theory, for instance, create a metacritical perspective within and across fields of study, such that the consideration of how a musician might interpret a painting or how a particular author reveals religious meanings in literature leads to a more critical awareness of fundamental questions about truth and values. The interdisciplinary knowledge structure is honed through a gradual advancement in higher-order cognition—specifically, metacognitive skills, critical thinking, and personal epistemology.

Interdisciplinary studies facilitate higher-order cognitive processing by motivating students to engage in deep learning. When students take a deep approach to learning, they seek meaning, reflect on what has been learned, and internalize knowledge by creating personal understanding (Entwistle & Ramsden, 1983). Deep learning is often contrasted with surface learning (e.g., memorization of facts) and characterized by important and long-standing changes in intellectual development. As an example, students in the M.A. in Humanities program often report changes in their teaching and reading, as well as life-changing alterations in the way they perceive their lives and work. One

student suggested her humanities coursework provided the "thread to stitch together the various tapestries of [her own] interests and aspirations." More generally, deep learning is manifested as a reduced reliance on external guidance, less absolute thinking, and increased confidence in one's beliefs and actions (Zhang & Richarde, 1999).

Critical thinking is another outcome of interdisciplinary programs. Researchers have demonstrated a relationship between college attendance and critical thinking, particularly in regard to weighting evidence, determining the validity of data-based generalizations or conclusions, and distinguishing between weak and strong arguments (e.g., Pascarella & Terezini, 1991). These findings extend to both traditional college students and adult learners (Klassen, 1983–1984). If students are adept at thinking critically, they are adept at "gathering, analyzing, synthesizing, and assessing information, as well as identifying misinformation, disinformation, prejudice, and one-sided 'monological' argumentation" (De Costa, 1986, p. 2). In integrated programs, students are challenged to determine the basis of arguments and analyze truth claims across disciplines (Kelder, 1992). Historical truths are reevaluated, for example, through the filters of artistic expression. A modern film version of a Verdi opera based on Shakespeare's rendering of older sources allows students to raise metacritical questions and synthesize fundamental issues across many time periods and cultures.

In addition to higher-order cognitive processing and critical thinking, interdisciplinary programs facilitate students' metacognitive skills. Gourgey (1998) offered this perspective on the nature of metacognition:

> "Whereas cognitive strategies enable one to *make* progress—to build knowledge—metacognitive strategies enable one to *monitor and improve* one's progress—to evaluate understanding and apply knowledge to new situations. Thus metacognition is vital to cognitive effectiveness." (p. 82)

Paris and Winograd (1990) specified two components of metacognition: self-appraisal and self-management of cognition. Hacker (1998) suggested that metacognition could be viewed as reflection on and deliberate use of one's intellectual weaponry, including self-analysis of task demands and regulation of cognitive strategies. Metacognitive strategies include connection of new information to previous knowledge, deliberate selection of thinking and problem-solving strategies, as well as planning, monitoring, and evaluation of thinking processes (Blakey & Spence, 1990). According to Gourgey (1998, p. 81), metacognitive skills include "knowing when and how to use different learning strategies;

how to [independently] plan, monitor, and control learning; and how to transfer learning skills acquired in the classroom to other contexts."

Positive relationships have been demonstrated between metacognitive skills and academic achievement, characterized by strengthened abilities to reason, think, and make decisions (e.g., Zhang & Richarde, 1999). Romainville (1994) found that students exhibiting higher levels of achievement were aware of their cognitive strategies and the factors influencing them. As compared to students exhibiting lesser levels of achievement, high achievers exhibited better structured metacognitive knowledge that was more highly centered on cognitive processes (Romainville, 1994, p. 363).

Students enrolled in interdisciplinary programs sharpen their metacognitive skills through deliberate reflection on their own ways of thinking. The process begins as learners apply interpretive tools across disciplines and thereby face their own internal set of implicit theories, assumptions, beliefs, and prejudices. Interdisciplinary learning outcomes, like developing a repertoire of ways to interpret a text, performance, or art object, enable students to expand the scope and meaning of their existing knowledge while suggesting new interpretive approaches. Outside the classroom, students can apply these insights to a deeper understanding of the ways in which they approach personal issues and problems in everyday life.

Epistemological development is another learning outcome of interdisciplinary programs. Epistemological beliefs are defined as implicit beliefs about the nature of knowledge and learning (Schommer, 1994). Such beliefs often include perspectives on the difficulty of knowledge acquisition, learner's control over learning, the nature of knowledge authority, relativism, uncertainty, and subjectivity. These beliefs affect the level of students' involvement in the learning process (Wineburg, 1991), academic persistence (Livengood, 1992), reading comprehension (Ryan, 1984), and ability to cope with ill-structured problems (Kuhn, 1992).

An important source of epistemological development is the conflict between a learner's personal epistemological beliefs and irresolute, complex information encountered in university courses (Perry, 1968). This conflict can be particularly intense in interdisciplinary programs, such as the M.A. in Humanities, due to the program's intent to expose learners to multiple perspectives and engage them in active knowledge construction and application. For example, by focusing on a core theme of "race in the humanities" learners will integrate points of view and interpretive strategies across several disciplines. Novelistic, cinematic,

religious, philosophical, artistic, or musical depictions of racial issues will contradict or complement one another in ways leading to a new critical awareness, inconsistent with the notion of certainty of knowledge and omniscient knowledge authority.

Similarly, dualistic thinkers may undergo change in their epistemological beliefs through the routine application of learned material to interdisciplinary issues or problems. Whereas dualistic thinkers define understanding of material as the ability to recall facts, relational thinkers check the level of their comprehension against their ability to apply newly learned facts to new situations (Ryan, 1984). Dualistic thinkers enrolled in an interdisciplinary program may experience pressure to resolve a conflict between their epistemological beliefs and the level of understanding required by their instructors.

Through revealed epistemological contradictions and application of knowledge to the program's main topic, interdisciplinary studies may accelerate a student's personal epistemological development. However, the level of intellectual sophistication at which interdisciplinary learners are expected to operate early on in the program may leave behind those less refined in their epistemological beliefs (Schommer, 1994). Students with naïve epistemological beliefs are likely to fail to comprehend sophisticated lines of argument until their epistemological perspectives pass through a fixed sequence of stages and reach more advanced levels (Kitchener & King, 1990). It may be possible, however, to minimize the distance between students' actual epistemological levels and their potential for development by placing problem-solving activities under the guidance of instructors or encouraging collaborations with more capable peers.

The Process of Interdisciplinary Learning

A comprehensive search of the educational literature revealed few theoretical frameworks that drew distinctions between traditional and integrated curricula and none that detailed specific outcomes expected at each stage of the interdisciplinary learning process. Consequently, we adapted Biggs and Collis' (1982) Structure of the Observed Learning Outcome or SOLO taxonomy, a model applicable to all types of curricula. The SOLO taxonomy describes several structural levels through which learners pass and defines observed learning outcomes at each structural level (Biggs & Collis, 1982). Structural levels include prestructural, unistructural, multistructural, relational, and extended abstract levels of operation. The definition of each level is presented in Table 2.

Table II
Biggs and Collis' (1982) Structural Learning Model

Structural Level	Observed Learning Outcomes Biggs & Collis (1982, p. 152)
Prestructural	The task is engaged, but the learner is distracted or misled by an irrelevant aspect belonging to a previous stage or mode.
Unistructural	The learner focuses on the relevant domain and picks one aspect with which to work.
Multistructural	The learner picks up more and more relevant or correct features but does not integrate them.
Relational	The learner integrates parts of the structure with each other so that the whole has a coherent structure and meaning.
Extended Abstract	The learner generalizes the structure to take in new and more abstract features, representing a higher mode of operation.

An adaptation of Biggs and Collis' model to interdisciplinary programs is presented in Table 3. The prestructural level was not considered due to its limited relevance.

At the unistructural level, the learner focuses attention on one relevant discipline. The unistructural pattern of thinking can be observed in some students at the early stages of interdisciplinary programs, such as the learners' first course in a relevant discipline. At this stage, the learner is able to identify how the discipline is related to the central theme of the program. The learner becomes familiar with the discipline's terminology and methodology, two aspects that foster declarative and procedural knowledge. Unistructural thinking is demonstrated when a learner approaches a recurring programmatic theme from the perspective of single discipline, such as English or Religion.

As a learner approaches the multistructural level, he or she acquires knowledge in several disciplines, but treats them independently. The multistructural level is characterized by discipline compartmentalization. Knowledge developed at this stage is multidisciplinary, rather than interdisciplinary, and characterized by a cognitive "juxtaposition of several disciplines with no direct attempt to integrate" (Jacobs, 1989, p. 8). The learner understands the central theme at the declarative level and is able to apply procedural knowledge gained in each discipline.

At this stage, learners may experience disorientation in their struggle to understand the nature of disciplinary distinction. As empirically demonstrated by Lea and Street (1998), "course switching" from one

Table III
Application of Biggs & Collis (1982) Structural Model to Interdisciplinary Learning

Structural Level	Description within a context of interdisciplinary learning	Outcomes
Uni-structural (uni-disciplinary)	Learner focuses on a relevant discipline.	Declarative and procedural knowledge in one discipline
Multi-structural (multi-disciplinary)	The learner acquires knowledge in several disciplines but does not integrate them.	Declarative and procedural knowledge in several disciplines that are related to a central theme; multidisciplinary thinking
Relational (inter-disciplinary, limited to one central theme or problem)	The learner integrates knowledge from several disciplines around a central theme. Critical thinking skills are being developed as the learner becomes aware of the strengths and limitations of the perspectives offered by each discipline.	Interdisciplinary content thinking (declarative and procedural knowledge); critical thinking skills; some metacognitive skills; advanced epistemological beliefs
Extended abstract (interdisci-plinary, extended to other themes or problems)	The learner acquires a knowledge structure that integrates interpretive tools (methodologies, theories, paradigms, concepts, etc.) from multiple disciplines. The learner uses metacognitive skills to monitor and evaluate his or her own thinking processes. The learner applies an interdisciplinary knowledge structure to new interdisciplinary problems or themes.	A well-developed interdisciplinary knowledge structure; interdisciplinary content thinking; critical thinking skills; metacognitive skills; highly advanced epistemological beliefs; transfer of interdisciplinary knowledge

discipline, course unit, or instructor to another in the program introduces conflict and uncertainty as students transition to a new set of implicit "epistemological presuppositions about the nature of academic knowledge and learning." (p. 162). It is not clear whether these types of conflicts would be exacerbated by interdisciplinary versus disciplinary curricula since interdisciplinary study necessarily provides a common

context for exploration of relevant perspectives, the interdisciplinary problem, issue, or theme.

If these discontinuities can be resolved, learners may ascend to the next stage of intellectual development—the relational level. At this level, a learner gives consideration to the relational structure of knowledge. As a result, the learner develops an ability to recognize the underlying relationships in the knowledge structure. The learner integrates knowledge through the use of metacognitive skills, including an analysis of thought processes, application of cognitive strategies, and control over learning and thinking. An interdisciplinary learner is likely to integrate knowledge in relation to a central theme by comparing and contrasting the interpretive tools offered by different disciplines. It can be argued that, when faced with an interdisciplinary issue, relational thinkers may incorporate facts, principles, or theories from multiple disciplines more readily than non-interdisciplinary learners. In the M.A. in Humanities, for example, learners encounter a diversity of opinion and gain insights into constructing complex claims when they compare how issues of race are interpreted by historians, poets, musicians, or moral philosophers.

Exposure to different interpretations of the same topic is likely to provoke a conflict in learners who believe in absolute knowledge handed down by authority. At the relational stage, the learner engages his or her critical thinking skills and becomes aware of the strengths and limitations of particular perspectives. The learner's epistemological beliefs are expected to depart from the notion of absolute knowledge and become more consistent with relational thinking, acknowledging subjective and uncertain qualities of knowledge. Thus, encounters with contrasting and conflicting perspectives offered by instructors in the M.A. in Humanities program are likely to stimulate student departure from absolute thinking.

At the extended abstract level, the learner develops an interdisciplinary knowledge structure that facilitates exploration of the program's central theme and represents the interrelationships between interpretive tools contributed by each discipline. This complex knowledge structure is derived through critical thinking and metacognitive skills that may be applied to other complex problems, whether similar to the central theme of an academic program (near transfer) or unrelated to it (far transfer). Such a knowledge structure, characterized by an internalization of integrated perspectives, might include insights into a social problem or public policy issue, an artistic vision, or historical perspective.

The epistemological beliefs underlying the extended abstract level embody a personal recognition of the dual validity of objective and subjective means of reasoning—two aspects of cognition represented in interdisciplinary problem-solving. Rather than perceiving knowledge as some static commodity, interdisciplinary learners are, arguably, more likely to perceive knowledge as a gradually acquired process of cognitive engagement, altered by both the analytical and experiential growth of the learner and the eventual assimilation of increasingly complex patterns of information.

In summary, learners at the extended abstract level are capable of true interdisciplinary thought—consisting of highly-developed knowledge structures and underlying epistemological beliefs, critical thinking and metacognitive skills, and the capacity to transfer interdisciplinary knowledge to other appropriate contexts.

This model (see Table 3) offers the following key features. First, it defines the structural levels through which interdisciplinary learners pass by building declarative and procedural knowledge in each of the disciplines, integrating the disciplines around the program's main focus to form a complex knowledge structure, and generalizing the acquired knowledge structure to other interdisciplinary problems, topic, or issues. The model also suggests how interdisciplinary learning facilitates specific learning outcomes, including interdisciplinary content thinking, reasoning skills, epistemology, and metacognition.

Conclusions

The interdisciplinary approach to teaching and learning focuses on the methodologies, interpretive tools, and language of several disciplines on a central problem, issue, or theme. As a consequence, students engaged in interdisciplinary programs are more likely to acquire integrated perspectives and solution-focused strategies, rather than content-specific knowledge derived from a single discipline.

Several arguments can be advanced in support of interdisciplinary learning: more comprehensive and holistic treatment of key topics and a deeper assimilation of multidisciplinary and interdisciplinary concepts. The anticipated learning outcomes of interdisciplinary studies include gradual advancement in metacognitive skills, critical thinking, and personal epistemology. Together, these higher learning outcomes contribute to a personalized integration and assimilation of knowledge transferable to other contexts, issues, or problems.

Because cognitive development and intellectual maturation are among the most important outcomes of interdisciplinary programs, assessment of student progress toward these milestones is as important as more traditional assessment of discipline-specific declarative and procedural knowledge.

The assessment of cognitive outcomes of interdisciplinary learning can provide educators with an insight into their students' development and forge a useful foundation for programmatic improvement. As addressed by Field, Lee, and Field (1994), "while the lack of a standard curriculum in interdisciplinary programs is usually thought of as a major disadvantage for the assessment of interdisciplinary education, it may be a major advantage in that it requires us to focus on the development of intellectual capability in the student rather than on a fixed body of information" (p. 70–71).

Proponents of the interdisciplinary approach contend that integrated curricula may help students to cope with increasingly complex and multifaceted work environments (Jacobs, 1989) and may aid in developing the problem-solving skills and complex perspectives most needed by modern society (Davis, 1995). In this article, we argued that intellectual maturation could be effectively developed through exposure to different disciplines and consistent application of multidisciplinary knowledge to the same relevant context. We have also proposed a framework that detailed the milestones achieved by learners at each stage of the interdisciplinary learning process. In particular, we specified changes in interdisciplinary learners' critical thinking ability, metacognitive skills, epistemological beliefs, and knowledge structures that represent frameworks of the relations between disciplinary perspectives derived from different disciplines. Much research is needed, however, to identify the criteria and evaluative strategies necessary to assess and enhance students' cognitive development throughout interdisciplinary study.

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