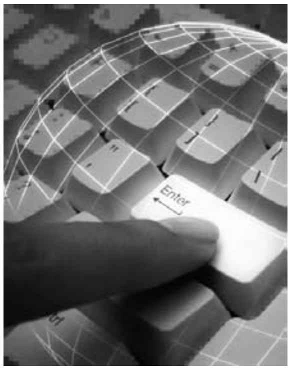

Online Jigsaw Science Inquiry for Preservice Teachers

Carmen Fies

Abstract

This article introduces an online jigsaw model for preservice teachers' science content learning. Following a description of the model and its developmental genesis, analysis of an external proficiency measure serves to evaluate the model's validity. Data stem from a sample of 333 students who completed physical science courses in either a face-to-face or online setting, and who participated in a state-mandated certification exam. An independent samples t-test of means of scores indicates that the two groups are not significantly different from each other. Based on this preliminary finding and the high student retention rate across semesters, the online jigsaw model appears to be a viable alternative to on-campus settings.

Introduction

Today's tertiary student population no longer consists solely of the traditional fresh-out-of-high-school-graduate. Many of our adult learners are returning to student life after some time in the work place, or after raising children. This growth trend is projected to continue and to demand attention (Snyder, Tan, & Hoffman, 2006, p. 277). According to the *Digest of Education Statistics 2005*, roughly 4 million students older than 29 years of age will be enrolled in college and university programs by 2010 (see Figure 1). Typically, these learners add college life to other obligations, which does not only mean a higher workload, but also necessitates special arrangements such as for childcare during class hours.

Online course work offers a viable alternative for this student demographic (Sikora, 2003). However, online courses are frequently criticized: they are said to lack in general rigor, in teacher-student and student-student interactions, as well as in support structures for meaningful hands-on and minds-on explorations. In addition, an Instructional Technology Council (2006) report indicates that, across 140 institutions, retention rates in online courses (72%) are lower than those in traditional classroom courses (78%).

This paper reports on an online physical science lecture and laboratory course set that, since its first offering in 2004, successfully meets learner needs. As will be shown, student learning outcomes are comparable to those of students in the face-to-face (F2F) classroom. Furthermore, retention rates are extremely high: between spring 2004 and summer 2005, a total of 128 students signed up for the online course set. Only two of those students withdrew, resulting in a retention rate of 98.4%.

The course set is part of a mandatory sequence of course work for students seeking elementary or generalist middle level teaching certification in the state of Texas. In the preexisting F2F format, the sequence of physical science topics in separate lecture and laboratory components (labs) are aligned so that students would work on the same concepts during the same weeks. However, typically labs and lecture are taught by different instructors and so variations in approach are unavoidable. Although the conceptual content of the online set mirrors that of the F2F companion, it does not simply consist of converted F2F materials, mimicking cor-

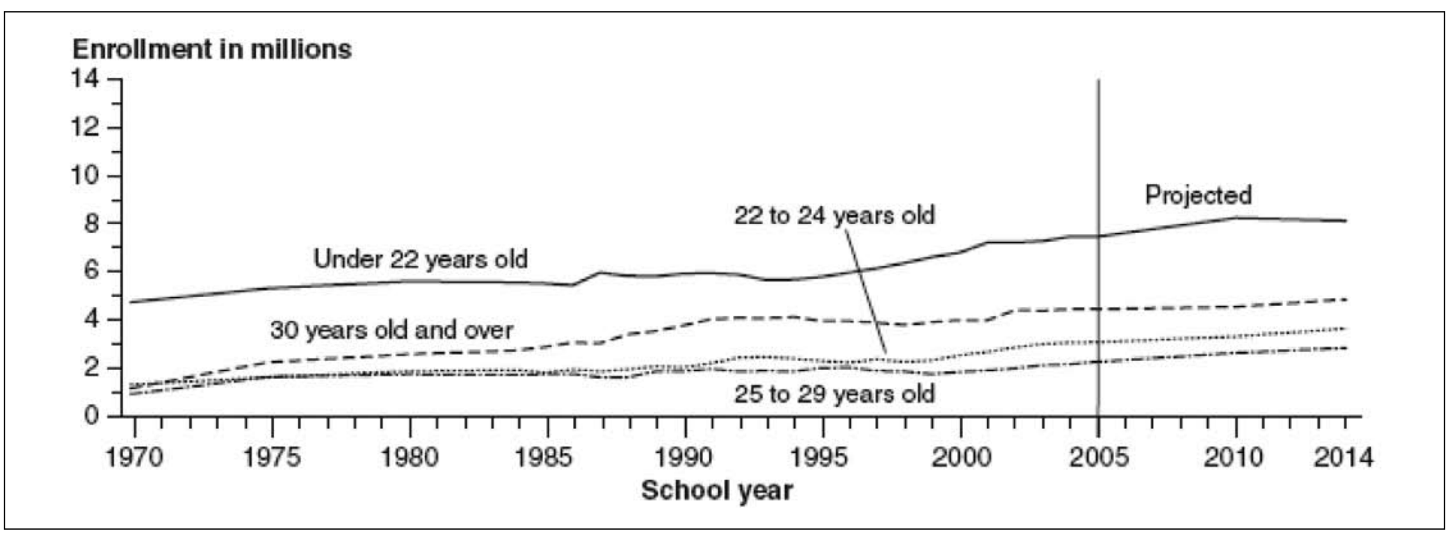

Figure 1. Enrollment in degree-granting institutions, by age: Fall 1970 through fall 2014. SOURCE: U.S. Department of Education, National Center for Education Statistics, Higher Education General Information Survey (HEGIS), "Fall Enrollment in Institutions of Higher Education" surveys, 1970 through 1985; 1986–87 through 2004–05 Integrated Postsecondary Education Data System, "Fall Enrollment Survey" (IPEDS-EF:86–99), and Spring 2001 through Spring 2005; and Projections of Education Statistics to 2014. (Snyder et al., 2006, p. 281)

respondence courses of times-gone-by. Rather, course development was guided by the recognition that rich and varied opportunities for discourse, as well as pedagogically and scientifically sound hands-on/minds-on experiences are critical components of learning.

Literature Review

General Learning Literature

Since much has been said about the origins of socially mediated constructivism, this article will only briefly remind the reader of the framework's Vygotskyan roots (Vygotsky, 1962, 1978). Learning in this context occurs in social interactions, where meaning making initially occurs through the scaffolding of more knowledgeable others until, finally, the Zone of Proximal Development (ZPD) no longer acts as obstacle.

Spawned by this foundational framework are a number of newer models, such as anchored instruction or situated learning (Cognition and Technology Group at Vanderbilt, 1990; Lave & Wenger, 1991; Resnick, 1987). The two ideas are closely related in that "situatedness"—a concept that is linked to the desire of providing a real world connection to school learning, as well as to the acceptance of the reciprocal influence of individual and environment on each other—can be considered to be an "anchoring" idea. Building on this idea are goal-based scenarios (Schank, Fano, Bell, & Jona, 1993/1994) where tasks are carried-out in virtual environments and students have opportunities to build specific skills in the process of executing tasks that are solidly based in real-world contexts. This connection to the "real world" requires that attention be paid to authentic problems and authentic problem-solving approaches. The aspect of authenticity is still debated in the literature. Although there are no doubts that authentic contexts are more likely to be engaging and motivating (Shaffer & Resnick, 1999), there remains the question of "Authentic to what?" In fact, can the school environment provide a platform that engages learners in scientifically authentic ways? Several studies report that the typical textbook task is hardly akin to authentic science (i.e., Brickhouse, 2005; Chinn & Malhotra, 2002; O'Connor, Godfrey, & Moses, 1998). In science education, the call for inquiry-based learning activities seeks to tap into the power of authentic experiences. Dewey considered inquiry to be a core principle in learning (Dewey, 1938, 1938/1963) and the National Science Education Standards strongly emphasize inquiry as process and content (National Research Council, 1996).

Vygotsky's (and Dewey's) claim for social interaction as critical component of learning is addressed in a number of community-based learning designs. The tenets of a community of practice (Lave & Wenger, 1991; Wenger, 1998) or community of learners (A. Brown & Campione, 1994; Rogoff, 1994) are rooted in out-of-school settings, but translate to school learning in their foundational recognition that learning occurs through negotiation and enculturation amongst specific groups of people interacting in a particular space and at a particular time (Bransford, Brown, & Cocking, 2000; Salomon & Perkins, 1998). A model proposed by Brown, Collins, and Duguid (1989) frames such interactions as a cognitive apprenticeship in which learners are mentored into a content area. Within communities of practice, cognitive apprenticeships and situated learning occur naturally.

Another conceptual strand supports the need for communal learning in recognizing knowledge as distributed amongst individuals: different learners bring different background knowledge—and different ways of knowing—to an interaction. This model of "distributed learning" emphasizes the symbiotic relationship between the individual learner and the group in which the learner participates (i.e., A. Brown et al., 1993; Dede, 2004; Guribye & Wasson, 2002; Hickey & Zuiker, 2003; Hutchins, 1995; Kilpatrick, Barrett, & Jones, 2003; T. Koschmann, 2003; Olson & Wisher, 2002; Otero, 2001; Puntambekar & Kolodner, 2005; Wilson, Ludwig-Hardman, Thornam, & Dunlap, 2004).

Participatory learning is described as follows by Barab et al. (2001): "Learning, from this perspective, is not the acquisition of facts and skills, but an activity involving the appropriation and construction of socially negotiated practices, understanding, and meanings through participation in a trajectory of experience" (p. 49). Participatory models include reciprocal teaching (Palincsar & Brown, 1984), the jigsaw model (Aronson, Blaney, Stephin, Sikes, & Snapp, 1978), and the idea of just-in-time teaching (Novak, Patterson, Gavrin, & Christian, 1999; Schank, 2002). All three rely on active participation of all learners and define the role of the teacher as that of a collaborator and supporter in the quest for new understandings. Critical is formative assessment and feedback as learners engage in problem-solving and meaning-making (Boston, 2002). Typical of classroom evaluations is the summative approach; this kind of testing occurs after completion of a segment, is tied to a grade, and does usually not provide opportunities for revision. Formative assessment, on the other hand, serves as a diagnostic tool; it serves specifically to provide feedback with the intent of instigating revision, and without attaching a grade to that evaluation.

Science education standards (e.g., American Association for the Advancement of Science, 1990; National Research Council, 1996) affirm communal and discursive learning in which learners engage in active inquiry to make meaning of science concepts. Learner-centered approaches (Bransford et al., 2000) in science education shift the role of the teacher from that of the "sage on the stage" to one of a more-knowledgeable supporting facilitator and collaborator. Problem-based learning (PBL), a model that supports communal learning within "real-world" and "messy" contexts, is one approach that aligns well here.

Online Learning Literature

Online learning environments clearly experience some of the same affordances and tensions as do F2F learning environments. After all, pedagogical models are not limited to F2F settings. A meta-analytical review of 86 studies indicates that online learning is a viable alternative to F2F settings (Shachar & Neumann, 2003); yet, learners miss F2F contact (Stodel, Thompson, & MacDonald, 2006). Although results from the earlier cited large-scale survey (Instructional Technology Council, 2006) clearly show a continued discrepancy in retention rates between distance education (72%) and F2F courses (78%), the demand for distance education courses exceeds availability at 70% of institutions participating in the survey.

The need to "get the mix [of interactions] right" (Anderson, 2003) for a diverse population of online learners points to balancing varied levels of interaction: at the core are student-student, student-teacher, as well as student-content, with additional spheres of interaction such as student-interface, teacher-teacher or content-content (Anderson, 2002, 2003; Moore, 1989; Muirhead & Juwah, 2004; Wagner, 1997; Woods & Baker, 2004). Figure 2 illustrates these multiple relationships as presented by Anderson (2003).

Further complicating the issue of balancing multiple interactional modalities is that what a teacher conceives as an interactive exchange may or may not match the perceptions of learners. It is critical that interactive loops close from the learners' point of view; that is, that there is feedback to a learner's statement (Yacci, 2000). Muirhead and Juwah's review of computer-mediated interactivity literature (2004) points to a general agreement on the complexity and critical role of interaction and interactivity in online education. Although it is reasonable to expect that at least the three core interactions take place in any formal learning environment, it may not be necessary to support all of them equally. In her "Equivalency Theorem," Anderson (2002) puts forth the following:

> Sufficient levels of deep and meaningful learning can be developed as long as one of the three forms of in-

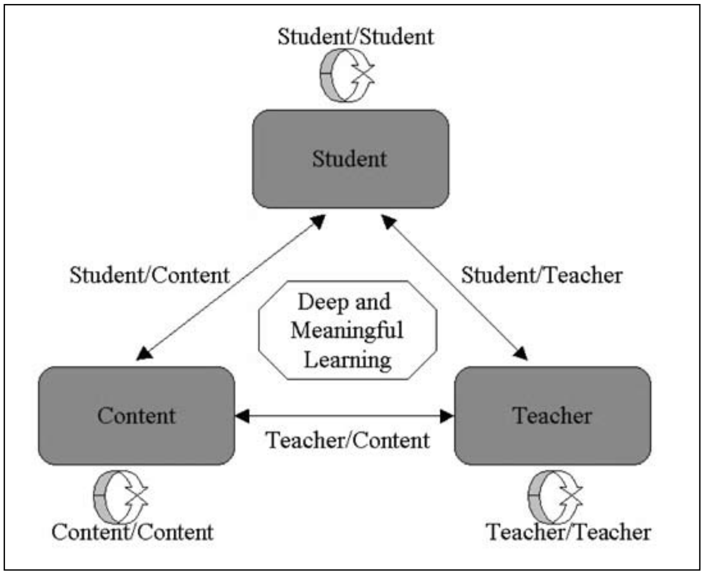

Figure 2: Model of Learning Interactions (Source: Anderson, 2003).

> teraction (student-teacher; student-student; student-content) are at very high levels. The other two may be offered at minimal levels or even eliminated without degrading the educational experience. (para. 10)

The literature describes communal models that are rich in discourse opportunities as capable of filling this need for personal interaction. The general importance and process of community building is emphasized as an antidote to attrition (i.e., Fottland, 2002; Rovai, 2002; Waltonen-Moore, Stuart, Newton, Oswald, & Varonis, 2006) and is widely accepted as core design element. Different flavors of community apply here, such as the idea of a "bounded" community (Wilson et al., 2004), or of a community of practice (i.e., Barab & Duffy, 2000; Lave & Wenger, 1991). The bounded community is one that exists within the confines of a particular learning setting, such as a course. As such, it exists in its intact form only throughout the period of the course's duration. Another aspect of great importance toward community-building is the consideration of a diverse population of learners. For example, a study of cultural differences amongst online learners led to the finding that Anglo-Saxon students preferred a learner-centered context and Asian students preferred a teacher-centered condition (Bauer, Chin, & Chang, 2000).

The Instructional Technology Council's survey of distance education experiences indicates that offering lab-based science courses online is met with strong faculty resistance (2006). One major concern is that, when learners are not exploring science within a well-equipped on campus laboratory, the lack of scientific equipment and low measurement accuracy may negate any learning value of possible explorations. A frequently used alternative to physical labs in both online and F2F settings is the virtual lab in form of microworlds and simulations (i.e., Horwitz, 2002; Kim, Jackson, Yarger, & Boysen, 2000). In the case of online science learning, Forinash & Wisman note that "[w]hether distance education is successful in maintaining experimentation as an important part of science education depends to a large degree upon the transparency, for both instructor and student, of the delivery technology" (2001, n. p.). Given that systems can be made to be transparent, online science learning benefits from the environment's high potential to support conceptual integration (Morrison, 2003).

The online environment supports:

- Through multi-media expanded opportunities for visual and audio reinforcement of ideas and trigger mechanism for reflection
- Non-linear thinking and enables associative reflection

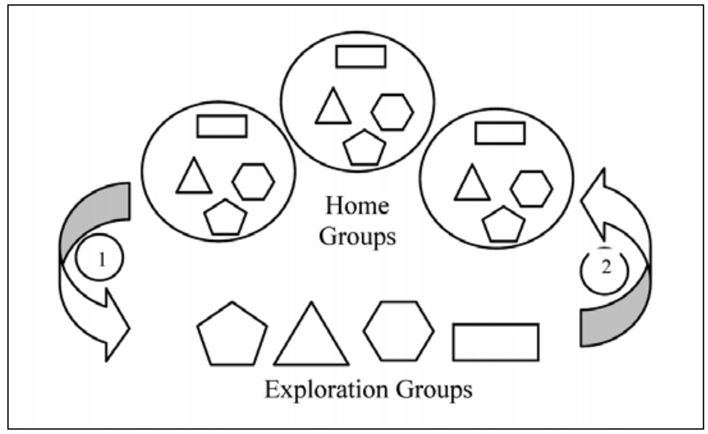

Figure 3: The Online Jigsaw Model (based on Aronson et al., 1978). The four students in a home group participate in different exploration group experiences and thus become experts on particular aspects of a scientific concept. They then reassemble into their home groups where each group member contributes his/her expertise towards the solution of an overarching problem.

- Adequate opportunity for dialogue using text and language for collaborative activities
- The making of connections and the sustaining of emergent meaning. (p. 6)

Not only do these characteristics match those of PBL environments, but findings from online PBL studies are promising (Cheaney & Ingebritsen, 2005; Steinkuehler, Derry, Hmelo-Silver, & Delmarcelle, 2002). Partially, these interactions cash in on current technologies that support virtual exchange of ideas in synchronous and asynchronous forms. In fact, if sufficiently scaffolded, online communications can be more focused and thus more effective than F2F discussions (Jonassen & Kwon, 2001).

Online Course Design

The tenets of socially mediated constructivist learning guided all design decisions. Communal PBL events (i.e., Koschmann, Kelson, Feltovich, & Barrows, 1996; Torp & Sage, 1998) are emphasized, as these align with the understanding that learning occurs through active participation in the sense-making of new ideas, takes place in social settings, and is framed by prior experiences.

An adaptation of the Jigsaw model, a well-established cooperative classroom learning strategy in F2F classrooms (Aronson et al., 1978), serves to engage learners in active, collaborative inquiry into science content and process within an online setting (Figure 3). A detailed description of the course's density unit follows below as an example of the online jigsaw model.

In this model, home groups (HGs) solve an application problem that requires incorporation of all exploration group (EGs) experiences. Therefore, it is necessary for each HG member to also be a member of a different EG and to become an expert on a different aspect of the problem to be solved. Within their EGs, learners engage in a hands-on and minds-on inquiry of an aspect of the larger HG problem. Although these science explorations are completed individually at home, results are compared and negotiated with others in the same EG. Once there is a consensus of how observations can be explained, each EG member reports findings to the HG s/he belongs to. In practice, most HGs begin to look for possible solutions to the application problem shortly after receiving the task. However, only once all EG assignments are completed and shared do HGs have all the information needed to negotiate possible solutions to the application problem. All units of the online course were designed according to this adaptation of the Jigsaw model. Students in F2F sections did not participate in such Jigsaw interactions as their lecture and laboratory experiences were separate from each other.

Very little direct teaching occurs within an online jigsaw unit. Creating a decentralized learning environment that heavily relies on individual participation and peer interactions encourages students to build contextual understanding via active intra- and interpersonal cognition in the traditions of Piaget and Vygotsky. The idea of varied types of knowledge residing within the group as a whole further aligns with tenets of distributed cognition (Hutchins, 1995). Since HG tasks are intentionally ill-structured to mirror real-world challenges, students have to try different pathways and multiple perspectives to find a suitable solution. This iterative struggle of meaning making is scaffolded via ongoing diagnosis and formative feedback (Puntambekar & Kolodner, 2005). To make sure the problem is not too far outside of what Vygotsky identified as Zone of Proximal Development (ZPD), all chosen experiments and thought exercises are grounded in everyday experiences. The intent is to elicit familiarity and to support connections of new ideas to existing frameworks. However, experiments and exercises are different enough from everyday experiences to avoid uncritical assimilation as defined by Piaget (1998), a practice in which new observations are cognitively shaped to fit with preexisting beliefs of how the world works (schemata). The provocation of a disequilibrium condition challenges learners to more carefully evaluate prior knowledge structures in light of new observations. Here, the learner ultimately adapts preexisting knowledge structures in order to account for new conceptual ideas via accommodation.

Students receive just-in-time support (Novak et al., 1999) and formative feedback (Etkina, 2002; Puntambekar & Kolodner, 2005) in order to facilitate and scaffold the learners' experiences. That is, the learning environment is responsive to learner needs as they occur, and provides ample opportunity for learners to iteratively refine understanding of a science concept throughout the exploration phase.

Example Unit: Density

One of the first units in the sequence centers on density, a concept that is critical in understanding a wide variety of physical phenomena, and a concept that is frequently problematic for learners (e.g., Fassoulopoulos, Kariotoglou, & Koumaras, 2003; Libarkin, Crockett, & Sadler, 2003; McDermott & Redish, 1999; Smith, Maclin, Grosslight, & Davis, 1997; Smith, Snir, & Grosslight, 1992). At the root of the conceptual discrepancy seems to be a tendency to simply focus on an object's size or mass, rather than the ratio relationship between the two. The unit is designed to challenge learners' forming understanding of density as (1) such a ratio, and (2) as an intensive property inherent in all matter. Students also investigate density changes due to variations in temperature or pressure.

The HG challenge assignment is intended to situate learning (J. S. Brown et al., 1989) by embedding it in authentic inquiry activity and to thus foster a process of enculturation to scientific thought. The unit's introduction assigns students an occupational role (i.e., scientist, engineer, or explorer) and scaffolds their interactions within a community of learners (Rogoff, 1994). Although authenticity in this case is not that of the field scientist, it is akin in the need to solve a complex problem by exploring a range of possible pathways (Brickhouse, 2005; Chinn & Malhotra, 2002; O'Connor et al., 1998).

Since the fate of the Titanic is widely known and efforts to raise it have been made, this topic acts as a realistic motivator for the HG work on density. The link to a real-world context is important, as widely described in the literature: For example, Dewey suggested an occupational focus in problem solving; Brown, Collins, and Duguid (1989) suggested situated learning as a form of enculturation.

Students are challenged to write a proposal to raise the Titanic. Although the submitted solution must be realistic in terms of density, acceptable solutions include suggestions such as the following: build a concrete encasement around the Titanic that reaches from the bottom of the ocean to its surface, and then add enough salt to the water within the encasement that its density exceeds that of the Titanic. Feedback to a suggestion such as this one includes prompting students to consider non-density aspects.

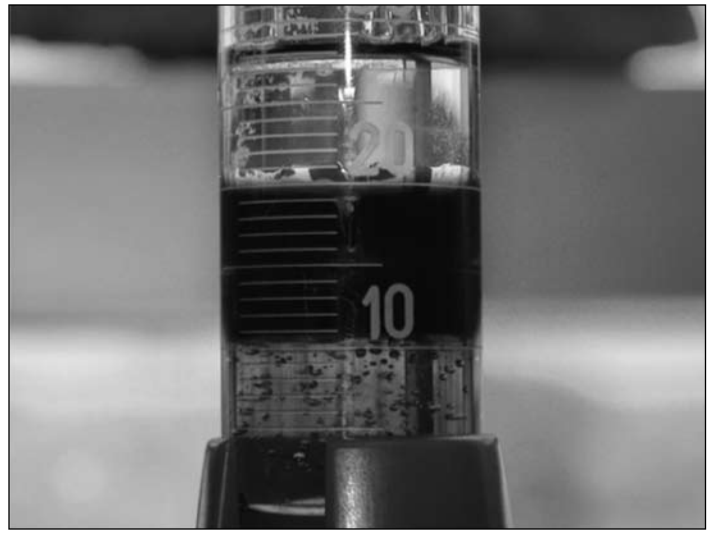

Figure 4: Density column.

In EGs, students inquire into density through both direct hands-on (or "real") and virtual explorations. Each participant is required to collaborate with others and to negotiate meaning amongst multiple interpretations in iterative cycles of articulation. The mixture of real and virtual is beneficial because the combination of both can mediate the shortcomings of each. An advantage of the real exploration is that the learner experiences the activity with all senses; yet, there are many explorations that either cannot be safely conducted in a home setting, or that do not allow for direct observation of the key behavior under study. Advantages of the virtual exploration are that the learner can simply reset and redo an experiment as many times as is necessary, that not directly observable processes can be modeled, and that there are no related dangers such as toxicity, flammability, or volatility. However, by the same token a virtual exploration cannot provide the learner with the same sensory input a real setting provides.

Most of the real explorations students use in the physical science course and laboratory are widely used, and many have been tested for many years. All virtual explorations were preexisting and available free-of-charge on the Internet. One of the EGs works with density issues comparing liquids, another works with liquids and gases, and a third with a combination of liquids and solids. Following are brief descriptions of two examples:

One of the at-home explorations students complete is to approximate the density of mustard. Students use common household substances (water, oil, syrup, and soy sauce) to create a density column (Figure 4) in a tall and narrow glass container. They calculate the densities of each, then assemble the column, and add a drop of mustard to observe the level of where it settles. That level indicates its approximate density value.

Another EG's inquiry work took place in an interactive online environment (http://www.eoascientific.com/interactive/weight_mass_volume_density_gravity/weight_mass_volume_density_gravity.html; unfortunately, the site is not available anymore at the time of this writing). In this flash animation, students were invited to investigate how a number of items compared in terms of mass, volume, as well as the effects of gravity on these items. Measurements of mass and volume provided the basis for density calculations; dropping each item in air and in a vacuum provided insights into the effects of air resistance and of air pressure. Amongst the more surprising findings was that a balloon will simply explode in a vacuum, prompting a search for explanations followed by peer discussions in which the strengths and weaknesses of each of these explanations is evaluated. This very much aligns with authentic scientific work as it is critical in both cases to not only find patterns in observations, but to also evaluate the merits of different possible explanations.

Student exploration reports are graded with a lab rubric that serves not only as an assessment tool, but also to guide students' thinking and writing about the completed work.

Data and Findings

Population and Setting

The same teacher taught all of the F2F lectures, some of the F2F labs, and all of the online sections of the physical science course set during four semesters (Spring 2004, Fall 2004, Spring 2005, Summer 2005). The vast majority of students in both the on-campus and online sections of the physical science course set are enrolled in either an elementary or middle school preservice teaching program. During the four comparison semesters, a total of 363 students completed the course set in face-to-face sections and a total of 132 students completed the course set online; thus the ratio is 2.75 F2F students for every one online student. On-campus sections were supported by a course management system, WebCT, which contained all PPT materials, links to online resources, discussion boards, and grade book. Online sections were administered via Blackboard, where, in addition to the materials and resources available for the F2F sections, the chat functionality was also employed.

External Measure of Outcomes

Only data from preservice teachers are included as the external evaluation point, the Texas Examination of Education Standards (TExES), is only available for this group. The TExES is the Texas state-required pass/fail certification measure, and is administered on a bimonthly basis in paper-based and/or online formats across 60 certification categories (for more detail, please see http://www.texes.ets.org/). Tests specific to a field of science consist of segments that measure the candidate's understanding of the science itself, and segments that measure the candidate's understanding of the teaching of science. Generalist tests, such as the EC-4 generalist, consist of a variety of domains, including science. The maximum score on any one TExES domain is 300, and a minimum score of 240 is necessary to pass that domain. Arguably, this measure provides stronger evidence of the online jigsaw model's effectiveness than within-course measurements as it serves as an unbiased comparison of student learning outcomes.

Since more students take the course on campus than online, unequal sample sizes are unavoidable. Out of the full set of 363 on-campus and 132 online students, TExES science domain scores were available for a total of 333 students: 257 students who completed the courses in F2F sections, and 76 students who completed these courses in the online setting.

Based on the results of an independent samples t-test, assuming equal variances (Levene's Test: $p > .05$), the two groups are not significantly different from each other when comparing means of science domain scores: $t(331) = -.775$, $p_{2\text{-tailed}} > .05$ (Table 1).

For a more fine-grained look at how student learning outcomes compare across the two settings, data specific to the topics taught within the physical science courses was obtained from the state certification site. The physical science component accounts for 21.7–25% of the science domain, depending on the particular field the preservice teacher seeks certification in (see Table 2).

Unfortunately, these data could only be obtained for a total of 96 students. Of these, 87 had completed the course set in F2F sections and 9 in online sections. Since, depending on the certification field, physical science competencies consisted of different proportions of the test, the number of correct responses was converted to a percentage out of the number of physical science questions asked within a test (% correct).

Table 1: Group Statistics and Independent Samples t-test for Science Domain Scores

Group Statistics

	Context	n	Mean	Std. Deviation	Std. Error Mean
TExES Science Score	Online	76	254.45	27.234	3.124
	Face-to-face	257	257.23	27.631	1.724

Independent Samples Test

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
TExES Science Score	-.775	331	.439	-2.786	3.596	-9.860	4.288

Table 2: TExES Science Competencies by Certification Field

Field	Area	Physical Science Competencies (%)	Competencies: All Science	Science Teaching & General	Physical Science	Earth & Life Science
101	Generalist EC-4	25	020-023 (4)	020 (1)	021 (1)	022-023 (2)
103	Bilingual Education, Generalist EC-4	25	024-027 (4)	024 (1)	025 (1)	026-027 (2)
111	Generalist 4-8	21.7	036-058 (23)	036-040 (5) 056-058 (3)	041-045 (5)	046-055 (10)
116	Science 4-8	21.7	001-023 (23)	001-005 (5) 021-023 (3)	006-010 (5)	011-020 (10)

Based on the results of an independent samples t-test on these data, assuming equal variances (Levene's Test: $p > .05$), the two groups are also not significantly different from each other when comparing means of physical science competency scores: $t(94) = -1.384$, $p_{2\text{-tailed}} > .05$ (Table 3, p. 90).

The non-significant difference findings for both science domain and physical science competency scores leads to the conclusion that students in both online and F2F sections are equally well prepared for their professional certification exams.

Conclusions

The purpose of this article is to introduce the online jigsaw model for preservice teacher science learning contexts. As evidenced by the data, the format works well to scaffold science learning and to provide learners with direct experience of the inquiry process. Both aspects are critical learning outcomes for the preservice teacher population. Science content knowledge must include an understanding of inquiry as the fundamental pathway to meaning making in fields of science.

As both the high retention rate and the TExES score comparison between the online and on-campus physical science course sections indicate, the online version is a feasible alternative to the F2F course set. However,

Table 3: Group Statistics and Independent Samples t-test for Physical Science Competency Scores

Group Statistics

	Context	N	Mean	Std. Deviation	Std. Error Mean
% correct	Online	9	38.89	25.345	8.448
	Face-to-face	87	52.30	27.889	2.990

Independent Samples Test

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
% correct	-1.384	94	.170	-13.410	9.693	-32.655	5.835

comparative analysis of learner perceptions and discourse analysis are necessary to gain insights into the model's motivational potential and its potential to support cognitive change. Further, the TExES science domain score is based on student learning in all science courses of the program sequence, not just the physical science course set; and most of the on-campus laboratory sections were taught by other instructors. However, since the subset of physical science scores also indicates that no statistically significant difference in test scores exists between F2F and online populations, the model appears to be a valid approach.

The jigsaw model provides a viable platform for varied layers of interaction within the online learning context. For the instructional designer, the greatest challenge is to select and/or create appropriate scientific inquiry experiences towards meaningful learner engagement. Specific to the preservice teacher population, a further challenge is to select inquiry experiences that can be directly translated into the future teachers' own classroom practice.

Acknowledgments

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