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Evaluation of Learning Environments of the UTeach Teacher Development Program for Secondary STEM Teachers

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ABSTRACT

The UTeach teacher development program prepares secondary science and mathematics teachers from recruited STEM majors in their field in numerous universities across the United States. A newly modified version of the Constructivist Learning Environment Survey (CLES) was used to evaluate differences among the preservice teachers' perceptions of the learning environment in all three of the learning environment settings (UTeach courses, STEM content courses, and K–12 field-experience classes) and how these changed as students progressed through the program. CLES2-CS-STEM-UTeach was validated for use in three learning settings and with preservice teachers. In addition to validating the questionnaire in multiple learning settings with 702 university students, the study revealed that students perceived their learning environments more positively in UTeach and field-experience classes than in STEM content classes.

OBJECTIVES

This paper describes how learning environment research was used to guide the design, implementation, and evaluation of the learning settings of the UTeach program utilizing a modified version of the Constructivist Learning Environment Survey (CLES) (Taylor, Dawson & Fraser, 1995; Taylor & Fraser, 1991). The objectives were to validate the CLES2-CS-STEM-UTEACH with preservice teachers; and to evaluate the effectiveness of UTeach in terms of preservice teachers' perceptions of their learning environments in three different settings: (1) their UTeach pedagogical content courses; (2) their STEM science and/or mathematics major courses; and (3) the FIELD classes that they observe during assigned practice teaching within public school primary and secondary science and mathematics classes.

THEORETICAL FRAMEWORK

UTeach Program

UTeach is a secondary science and mathematics teacher development program in universities across the United States (UTeach Institute, 2015a). UTeach was created to attract science and mathematics majors into secondary teaching careers, through an advanced field-intensive curriculum, and to promote professional retention through substantial support and professional development (UTeach Institute, 2014). "Congress and the National Academy of Sciences have singled out UTeach … as a promising model to help fill a national shortage of qualified schoolteachers in science and mathematics" (Brainard, 2007, para 4). By 2014, UTeach had been replicated at over 40 universities in 19 states across the country, and 2100 graduates from the program (UTeach Institute, 2015a).

Science and mathematics majors are recruited to sample teaching as an alternative career, with the UTeach coursework fitting into their degree plans and containing eight courses prior to student practice teaching (see Table 1). UTeach students begin teaching in public school classrooms during the first professional development class. They are taught pedagogically-modelled science and mathematics education courses within the UTeach model, but their core courses are taught within the departments from which they will earn their degrees (UTeach Institute, 2014). Thus, they are able to determine if teaching is a fit for them early in their college careers. This contrasts with traditional teacher preparation programs in which students complete all of their pedagogical coursework before ever teaching in a pre-college classroom (Brainard, 2007).

Table 1. UTeach Course Sequence if Entering in Freshman Fall Semester

Year 1/ Freshman		Year 2/ Sophomore		Year 3/ Junior		Year 4/ Senior	
Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
Step 1	Step 2	Knowing & Learning	Classroom Interactions	Perspectives	Research Methods	Project Based Instruction	Apprentice Teaching/ Seminar

Adapted from UTeach Austin, Professional Development Sequence, 2012

Learning Environments

A constructivist learning environment is one in which students are co-constructors of their own knowledge (Fraser, 1998a). In the *Blueprints for Reform* Project 2061, a suggested approach for improving science teacher education is that "students should be allowed to become active learners, have first-hand experience with making connections between their own ideas and the knowledge they develop in courses, and participate in classes where faculty model a teaching style that is conducive to active learning" (AAAS, 1998, Teacher Education, ¶ 11). The importance of active learning dates back to Jean Piaget (1958) who theorized that assimilation and accommodation require an active learner, not a passive one, because problem-solving skills cannot be taught and they must be discovered. Within the classroom, learning should be student centered and accomplished through active discovery learning. The role of the teacher is to facilitate learning, rather than direct instruction. Active learning and constructing knowledge are very similar (McLeod, 2015). Lev Vygotsky's (1934, 1978) social constructivist theory emphasizes social contexts of learning and that knowledge is mutually built and constructed. By interacting with others students, they have the opportunity to share their views and thus generate a shared understanding related to the concept. Vygotsky's theories of education and instruction support instructional concepts such as "scaffolding" and "apprenticeship", in which teachers or more-advanced peers help to structure or arrange a task so that a novice can work on it successfully. Also, Vygotsky's theories lead into collaborative learning, suggesting that group members should have different levels of ability so that more-advanced peers can help less- advanced members to operate within their learning zone (McLeod, 2014).

Attempting to improve and develop a teacher preparation program requires reflection on and inquiry into its own practice as a way to measure its success. Further, teacher preparation programs are unique in that students arrive with a great deal of perceived knowledge regarding how to teach and the best ways to teach based on their personal world views of educational experiences as students. The students' world views lead to strong preconceptions about how to be an effective teacher or an effective learner, even though they might be early in their teacher education development (Harrington & Enochs, 2009; adapted from Grossman, 1990; Lortie, 1975*;* National Council of Teachers of Mathematics [NCTM], 2000). Thus, "any research on a teacher preparation program must acknowledge the difficult position that preservice teachers are in when they attempt to balance the theory from their coursework with what they are seeing in the field" and how these sometimes disparate schema can enhance each other (Harrington & Enochs, 2009, p. 63). The learning environments of preservice teachers need to be addressed in the various classroom roles in which they find themselves: students in their core classes, students in their preservice education classes, and when they are observing their K–12 school mentors in action. The learning environments of the participants within the program are a prime focus for evaluating the effectiveness of the program.

Learning environments research is known for the variety of robust, economical, and well- validated questionnaires that allow for the perspectives of students rather than trained observers or professionals (Aldridge & Fraser, 2008; Fraser, 1998b, 2012; Fraser, Giddings & McRobbie, 1995; Taylor, Fraser & Fisher, 1997). Of particular importance, the Constructivist Learning Environment Survey (CLES) was developed with a focus on students as the co-constructors of their own knowledge and to assess the degree in which a classroom is consistent with this constructivist model (Fraser, 1998b; Taylor, Dawson, & Fraser, 1995; Taylor, Fraser, & Fisher, 1997). The CLES has had several modifications and, in prior research, it has consistently been found to be valid and reliable. The CLES has been validated in multiple countries, languages and settings, including the USA (Long & Fraser, 2015; Nix, Fraser & Ledbetter, 2005), South Africa (Aldridge, Fraser & Sebela, 2004), Australia and Taiwan (Aldridge et al., 2000), Korea (Kim, Fisher & Fraser, 1999) and Singapore (Koh & Fraser (2014).

The CLES2 is a more-economical version with a reduced number of questions (Johnson & McClure, 2004). The CLES-CS is a comparative version with the scale responses set up in side-by-side columns. These two versions were combined into the CLES2-CS (Nix, Fraser & Ledbetter, 2005). The UTeach model of instruction and FIELD work have a heavy emphasis on inquiry and the 5E learning constructivist learning models (Cavanagh, 2007). The established validity and usefulness of the CLES with teachers and a variety of students was important when selecting a learning instrument questionnaire to answer our research questions regarding preservice teachers' perceptions.

METHODS

The CLES2-CS was revised in the current study to permit students to provide on a single form their perceptions of each of the three learning environments to which they are exposed: UTeach preservice courses, university STEM (Science, Technology, Engineering, and Mathematics) courses, and their FIELD K–12 public school courses. The CLES2-CS-STEM-UTeach involves modifications to the previous version: THIS classroom and OTHER classroom were changed to UTeach and STEM classes, respectively; a third column was added for FIELD classes; and prompt edits were made so that questions refer to STEM - not just science. Figure 1 illustrates this newly-modified version of the CLES, the CLES2-CS-STEM-UTeach, with its three-column format.

<table>
<tr><td colspan="10">I learn about the world outside of school</td></tr>
<tr><td colspan="5">In UTeach classes…</td><td colspan="5">In my STEM classes….</td></tr>
<tr><td>Almost Always</td><td>Often</td><td>Sometimes</td><td>Seldom</td><td>Almost Never</td><td>Almost Always</td><td>Often</td><td>Sometimes</td><td>Seldom</td><td>Almost Never</td></tr>
<tr><td colspan="10">If enrolled in a UTeach FIELD course, answer based on your FIELD observation (mentor) classroom….</td></tr>
<tr><td colspan="2">Almost Always</td><td colspan="2">Often</td><td colspan="2">Sometimes</td><td colspan="2">Seldom</td><td colspan="2">Almost Never</td></tr>
</table>

Adapted from Nix, Fraser, & Ledbetter (2005).

Figure 1. Sample Item Illustrating the Comparative Format of the Constructivist Learning Environment Survey (CLES2-CS-STEM-UTeach).

Sample

The university site chosen was one of the first replication sites in the UTeach expansion program (The UTeach Institute, 2015b). FIELD experiences took place in K–12 public schools that are geographically near the university and involved a range from upper-elementary science classrooms to single subject (mathematics or science) secondary-school classrooms.

UTeach students completed the CLES2-CS-STEM-UTeach at the end of each semester for four consecutive semesters in all the UTeach required courses. Although the study included samples of students from each level of the UTeach program, time limitations prevented the tracking of individual students from their initial UTeach course through to their last course (refer to Table 1). There were 702 CLES2-CS-STEM-UTeach surveys collected from across the UTeach program courses, but only 575 were from students in courses with a FIELD component. The validation and reliability analyses involved responses from the UTeach and STEM settings (N = 702) and the FIELD setting (N = 575), whereas the comparisons of the three settings involved N= 575.

ANALYSES AND RESULTS

Validity and Reliability of the CLES2-CS-STEM-UTeach

To check the structure of the CLES2-CS-STEM-UTeach, principal axis factor analysis with varimax rotation and Kaiser normalization was carried out for responses to the 20 items separately for each of the three samples (STEM, UTeach, and FIELD). The two criteria for the retention of any item were it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with each of the other four scales. The factor analysis results reported in Table 2 show that these two criteria were met for all items for each sample with only these exceptions: Item US4 had a factor loading of less than 0.40 on its own scale and greater than 0.40 on the Critical Voice scale for the UTeach sample; Item CV1 had a factor loading of greater than 0.40 on the Uncertainty of Science scale for the FIELD sample; and Item SC4 had a factor loading of less than 0.40 on its own scale for the FIELD sample.

The bottom of Table 2 reports the proportion of variance accounted for by each scale for each sample. The total proportion of variance accounted for by all five scales was 67.9% for STEM classes, 63.2% for UTeach classes, and 68.5%. Table 2 also reports that the Cronbach alpha reliability coefficient for different scales ranged from 0.68 to 0.85 for UTeach, from 0.72 to 0.92 for STEM, and from 0.76 to 0.88 for FIELD. According to George and Mallery (2003), these reliability values typically fall in the good to excellent range. Overall, the results in Table 2 support the factorial validity and internal consistency reliability of our version of the CLES for our three different types of classes.

Table 2. Factor Analysis Results (Factor Loadings, % Variance, and Eigenvalues) and Reliability (Alpha Coefficient) for CLES Scales for Three Samples (STEM Classes, UTeach Classes, and Field Classes)

Item	Factor Loadings														
	Personal Relevance			Uncertainty of Science			Critical Voice			Shared Control			Student Negotiation		
	STEM	UTeach	Field	STEM	UTeach	Field	STEM	UTeach	Field	STEM	UTeach	Field	STEM	UTeach	Field
PR1	0.69	0.69	0.67												
PR2	0.72	0.65	0.75												
PR3	0.75	0.57	0.65												
PR4	0.78	0.64	0.77												
US1				0.63	0.52	0.54									
US2				0.52	0.62	0.69									
US3				0.52	0.52	0.57									
US4				0.43	–	0.45		0.49							
CV1						0.50	0.46	0.52	0.54						
CV2							0.48	0.47	0.52						
CV3							0.75	0.71	0.68						
CV4							0.74	0.68	0.77						
SC1										0.72	0.72	0.74			
SC2										0.63	0.75	0.71			
SC3										0.85	0.74	0.81			
SC4										0.44	0.42				
SN1													0.76	0.64	0.74
SN2													0.88	0.69	0.81
SN3													0.86	0.77	0.74
SN4													0.77	0.68	0.60
% Variance	12.0	6.5	9.2	5.7	5.7	6.2	6.4	9.2	7.1	9.5	7.9	7.8	34.5	33.9	38.2
Eigenvalue	2.4	1.3	1.8	1.1	1.1	1.2	1.3	1.8	1.4	1.9	1.6	1.6	6.9	6.8	7.6
α Reliability	0.86	0.80	0.86	0.72	0.68	0.76	0.79	0.74	0.80	0.08	0.81	0.88	0.92	0.85	0.86

N=702 (STEM or UTeach classes), *N*=575 (Field classes)
Factor loadings less than 0.40 have been omitted from table.
Principal axis factoring with varimax rotation and Kaiser normalization
Total variance = 67.9% (STEM classes), 63.2% (UTeach classes), 68.5% (Field classes)

Comparison of the Learning Environments of Three Settings

Differences between preservice teachers' perceptions of the learning environment in the three different settings were investigated using MANOVA (with the five CLES scales as the dependent variables and the setting as the independent variable) for the sample of 575 students. Because MANOVA yielded statistically significant differences between settings for the set of dependent variables as a whole using Wilks' lambda criterion, the ANOVA results for each individual CLES scale were interpreted, as reported in Table 3.

Table 3. Statistical Significance (*F*) and Effect Size (Partial Eta^2) from MANOVA/ANOVAs with Repeated Measures for Overall Differences between Three Instructional Groups (UTeach, FIELD, STEM) for Five CLES Scales

CLES Scale	Overall Difference Between Three Groups	
	F	Partial Eta^2
Personal Relevance	96.58**	0.10
Uncertainty of Science	164.92**	0.16
Critical Voice	238.60**	0.22
Shared Control	449.99**	0.34
Student Negotiation	131.41**	0.13

MANOVA results: F = 89.39**, Wilks' lambda = 0.63, partial eta^2 =0.98
N = 575 in each group
**p<0.01

Table 3's results for each of the five CLES2-CS-STEM-UTeach scales for the three-level instructional variable shows that differences between instructional groups were statistically significant for every CLES scale and that the proportion of variance accounted for (partial eta^2) ranged from 0.10 for Personal Relevance to 0.34 for Shared Control (which is relatively large). Between-group differences were smallest for Personal Relevance. Shared Control had the largest between-group differences, possibly because of the manner in which the STEM courses are taught at the university level. As students progressed through the program, these overall trends in their perceptions of the learning environment settings continued to show that UTeach classes and FIELD classes were perceived as more positive learning environments than STEM classes.

In order to further clarify and interpret the significant differences for the overall comparison of three instructional settings for each CLES2-CS-STEM-UTeach scale, we used paired *t*-tests and Cohen's *d* effect sizes in looking at pairwise differences. Table 4 reports that these differences between each of the three pairs of instructional treatments were significant for every CLES scale at the 0.01 level. Table 4 shows that the effect sizes for different CLES scales generally were relatively large and ranged from 0.13 to 0.72 for the comparison of UTeach with FIELD classes, from 0.60 to 0.99 for the comparison of FIELD and STEM classes, and from 0.77 to 1.83 for the comparison of UTeach and STEM classes. Overall, the UTeach learning environment was significantly more positive than in the STEM and FIELD components; and the FIELD setting (where applicable) was significantly more positive than the STEM courses.

Table 4. Effect Size (Cohen's *d*) and Statistical Significance (Paired *t*-test Results) for Pairwise Differences between Three Instructional Groups (UTeach, FIELD, STEM) for Five CLES Scales

CLES Scale	Pairwise Difference between Three Groups					
	UTeach vs FIELD		FIELD vs STEM		UTeach vs STEM	
	d	*t*	*d*	*t*	*d*	*t*
Personal Relevance	0.13	3.16**	0.60	11.38**	0.77	13.50**
Uncertainty of Science	0.41	9.32**	0.63	12.83**	1.09	20.41**
Critical Voice	0.45	9.60**	0.78	15.70**	1.26	23.93**
Shared Control	0.72	16.19**	0.99	21.66**	1.83	34.99**
Student Negotiation	0.35	7.89**	0.96	10.64**	1.56	16.16**

$N = 575$
$^{**}p<0.01$
d = Cohen's effect size (difference between means divided by pooled SD)

Figure 2 is a visual representation of the group means across the three settings. Item means are based on a frequency scale in which 1 = Almost Never, 2 = Seldom, 3 = Sometimes, 4 = Often, and 5 = Almost Always. Therefore, UTeach and FIELD means tended to fall in the *Often* range while means for the STEM classes were in the *Seldom* to *Sometimes* range. The UTeach and FIELD settings reflected a positive learning environment. The STEM classes had a learning environment that was perceived as less positive than the other two settings. The profiles of learning environment scores highlight and illustrate the main differences between settings:

- The perceived learning environment was more positive for UTeach settings than for FIELD settings and STEM settings (with the exception of the Personal Relevance scale for UTeach and FIELD settings)
- The perceived learning environment was more positive for FIELD settings than for STEM settings.
- The differences between FIELD and STEM settings in learning environment were larger than the differences between UTeach and FIELD settings.

For each of the three instructional settings, the lowest scores occurred for Shared Control and the highest scores occurred for Critical Voice (which refers to the legitimacy of expressing a critical opinion). Shared Control refers to participation in planning, conducting, and assessing learning. Although Critical Voice scores were the highest of all scales, STEM classes were perceived to have less Critical Voice than the other classes.

Shared Control was higher in UTeach classes probably because students chose which lessons to conduct and how to teach them (within a format) when they went out to the field for their practice lessons. Students often had some curriculum choices in their field classes, whereas most STEM classes allowed no choices in how or what students learn from their university professors.

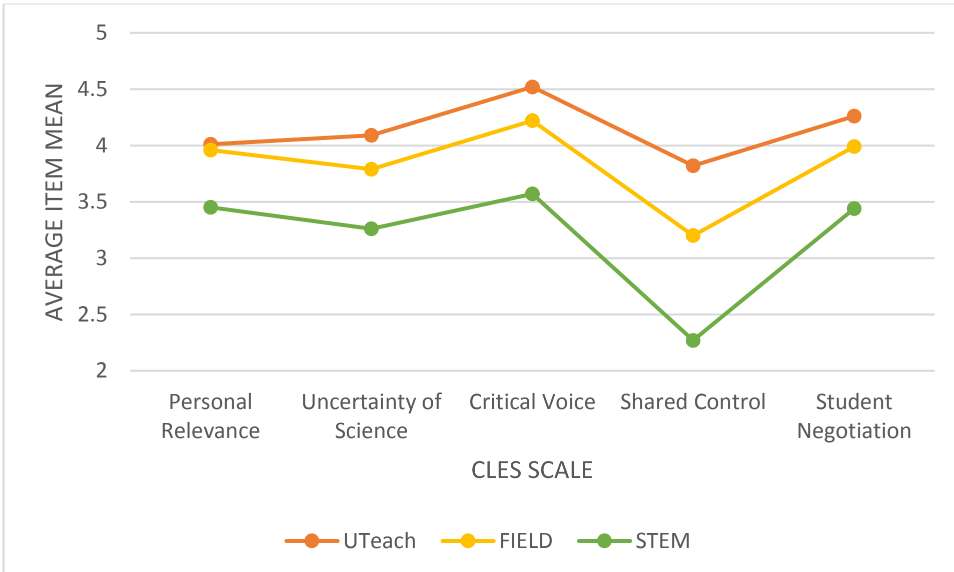

Figure 2. CLES Scale Means across the Three Learning Settings (UTeach, FIELD, STEM)

SIGNIFICANCE OF THE STUDY

Very few past studies have delved into the learning environments of preservice teacher education. Training teachers in the best way to teach future generations includes not only pedagogy, the lesson cycle and technology, but also the importance of the classroom climate to preservice teachers' learning and their students' learning in their future school classrooms. We therefore need to assess which classroom climates preservice teachers find more positive and what changes can be made in the light of these perceptions.

This study drew on the previously-validated CLES and further validated a modified version of it with preservice teachers. In addition, this study evaluated multiple learning environments (UTeach courses, STEM courses, and K–12 FIELD courses) over four semesters, thus allowing the monitoring of changes over time in preservice teachers' perceptions of the varied learning environments as they learn more educational theory. This is the first known study to use the CLES to evaluate three different settings at the same time. Therefore, our research with this version of the CLES is significant for the field of learning environments research.

This study's analyses show that students prefer the classroom learning environments of their UTeach and FIELD settings over their STEM classroom environments. This is consistent with the goal of the FIELD classes to act as preservice laboratories rather than unrelated, disjointed, and confusing ‘real world’ examples (Harrington & Enochs, 2009). The more positive perceptions of UTeach and FIELD over STEM classes reinforce the idea that students preferred a constructivist learning environment over the traditional lecture learning environment experienced in most STEM courses. Based on these results, it appears that UTeach learning environments could be meeting the needs of the students better than STEM courses. Professional development for STEM professors is recommended in an attempt to improve the learning environment and therefore learning in STEM courses.

Research complies with the AERA Code of Ethics and has been approved by an Institutional Review Board at two universities.

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