Influence of Collaborative Curriculum Design on Educational Beliefs, Communities of Practitioners, and Classroom Practice in Transportation Engineering Education

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Abstract: The development and widespread implementation of best practices in transportation engineering classrooms is important in attracting and retaining the next generation of transportation engineers. Engineering education professionals have uncovered many best practices in the field; however, the process of effectively disseminating and ultimately achieving the widespread adoption of these best practices by others is not yet well understood. Sixty participants, including faculty members, Ph.D. students, and public-sector employees, attended a transportation engineering education workshop convened in Seattle to promote the collaborative development and adoption of active learning and conceptual exercises in the introduction to transportation engineering class. Participant assessments were conducted in the form of presurvey, postsurvey, and follow-up survey. Results showed immediately positive shifts in participant beliefs about the importance of active learning and conceptual exercises, with declines during the follow-up period, an increased density and connectivity of curriculum-development networks, and extensive reports of valuable experiences and influences from the workshop. **DOI: 10.1061/(ASCE)EI.1943-5541.0000196.**

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Introduction

A large body of evidence suggests that student learning and other outcomes improve when students are doing something other than listening and taking notes in the classroom (e.g., Hake 1998; Hake 2002; Chi 2009). However, despite evidence for the value of these activities and access to a variety of resources that can be used to support them, most engineering faculty members still engage primarily in a lecture approach (Borrego et al. 2010); transportation engineering is no exception.

The first transportation engineering class at the undergraduate level in a civil engineering program poses significant challenges (Bill et al. 2011; Kyte 2013). These challenges include making tradeoffs between breadth and depth of learning, addressing a lack of sequential progression across multiple classes, and capturing the interest of students who are required to participate in the class as a program requirement. Implementation of active learning, which can be defined as activities other than merely listening and taking notes (explained further in the subsequent section), has the potential to improve student engagement in the face of these challenges.

The National Transportation Curriculum Project (NTCP), a consortium of researchers from eight colleges and universities, formed as a collaborative effort to respond to these challenges and improve transportation engineering education. In 2012, the NTCP hosted the Transportation Engineering Education Workshop (TEEW) to facilitate the adoption of active learning and conceptual-assessment exercises by faculty who teach the first transportation engineering class at the undergraduate level in a civil engineering curriculum. The TEEW provided the opportunity for groups of faculty to collaboratively develop active learning and conceptual-assessment exercises in a process scaffolded by short presentations and demonstrations, and punctuated by direct feedback by nationally recognized experts in these areas.

The objective of the workshop was to facilitate changes in transportation engineering faculty members' attitudes and actions. Such change can be encouraged by shifting faculty members' beliefs about the importance of active learning, and strengthening a curriculum-development network that provides materials and resources related to change. We hypothesized that a workshop in which faculty members (1) acquired tools for the design of active learning and conceptual-assessment activities, (2) applied those tools in a collaborative environment, and (3) developed a network of similarly-motivated colleagues would affect positive change in

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participants' attitudes and actions with respect to active learning and conceptual assessment. Shifts in faculty beliefs toward active learning and the density and connectivity of their curriculum-development networks related to teaching practices were evaluated over time, and the effect of the TEEW was assessed with reflective open-ended survey questions. This paper describes the rationale for adoption of active learning and conceptual exercises, the workshop and materials produced from the workshop, and the evaluation of the effectiveness of the workshop.

Background

The NTCP is concerned with the development, dissemination, and widespread adoption of curricular materials and best practices in transportation engineering education (Kyte 2013). Fig. 1 describes the NTCP starting with inputs such as knowledge and time of faculty and students, resulting in outputs such as conferences and workshops, and outcomes such as building a curriculum-development network committed to transportation engineering education. To date, project members have developed learning outcomes and associated knowledge tables for the introductory transportation engineering course (Bill et al. 2011), which were piloted at three institutions (Young et al. 2012). The workshop described in this paper resulted from NTCP members' efforts to engage a broader group of faculty members in this work by (1) developing the capacity and enthusiasm of participants for creating and implementing active learning and conceptual-assessment activities, and (2) building a network of colleagues engaged in these activities (a curriculum-development network).

Active Learning

Engineering faculty members have not widely implemented newer pedagogical approaches that have been proven to be effective, and adoption occurs slowly. Borrego et al. (2010) found that awareness of innovative educational approaches was high among engineering faculty members, but that adoption rates were much lower; that is, the stumbling block was not awareness but implementation. One such pedagogical approach is active learning. For the purpose of this paper, active learning is considered to be any student activity other than listening and taking notes, ranging from responding to instructor questions to working on challenging conceptual-design problems with other students and more experienced tutors. Evidence exists that active learning in engineering, science, and mathematics courses improves student learning and other important student outcomes, such as their belief that they can succeed in engineering (e.g., Hake 2002; Prince 2004; Chi 2009).

The most contemporary and by far the most complete analysis of the effectiveness of different active learning environments was conducted by Chi (2009). Chi describes three different kinds of learning environments: active, constructive, and interactive. According to Chi, an active-learning environment engages students in individual activities that are not particularly cognitively challenging, such as taking notes or highlighting passages. Students in a constructive-learning environment engage in activities that are more difficult than the material students have recently learned, such as combining multiple concepts to solve a more difficult problem than has been solved before. Finally, in an interactive environment, students perform constructive activities with other students. This operationalization of active-learning environments is important because Chi found that interactive activities have a greater effect on student learning than those of constructive activities, which in turn have a greater effect than those of simpler active-learning activities. As defined previously, we do not include Chi's definition of an active-learning environment into our definition; rather, we include the levels designated as constructive and interactive. A critical component of the active-learning classroom is the difficulty of the activities in which students engage. If the activities are too simple, then students will not work together (Brown et al. 2009); if they are too difficult, then students will become frustrated and give up.

Conceptual Assessment

Conceptual assessments have been implemented in active-learning environments to foster student learning of concepts, as opposed

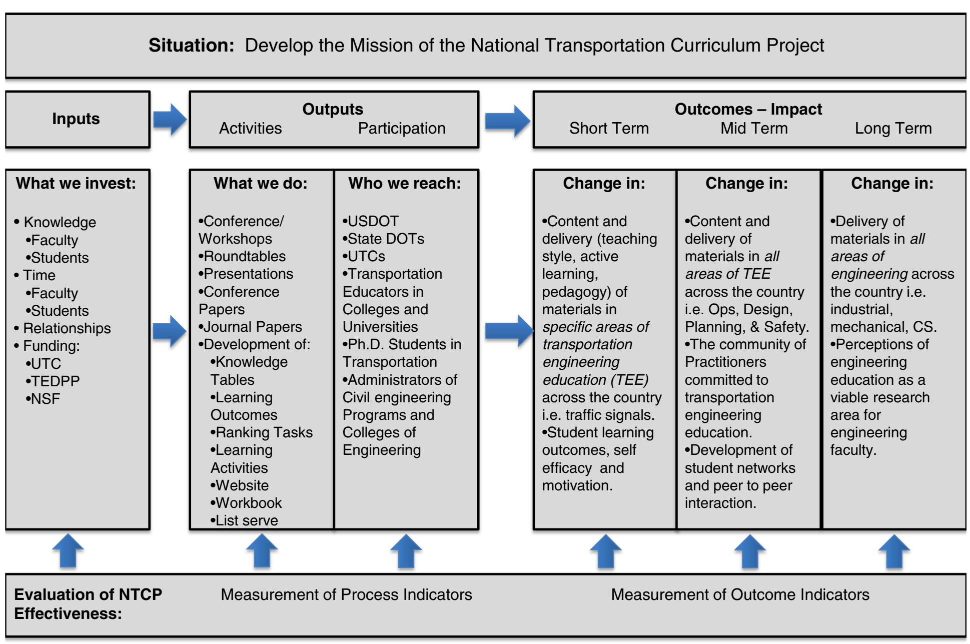


Fig. 1. Logic model of the National Transportation Curriculum Project

to the memorization and strict application of equations. They are characterized by solutions that require minimal or no need for equations and calculations, if the user understands the concepts. A ranking task (O'Kuma et al. 2003; Brown and Poor 2010) is an example of a conceptual assessment. In a ranking task, students are provided with four to six scenarios and asked to rank the scenarios based on specified criteria. For example, Fig. 2 shows a ranking task related to a specific element of roadway design, super elevation (or banking) on horizontal curves. This ranking task is designed to be solved almost immediately by an expert without the use of calculations; however, a student might require an extended period of time and may need to complete some calculations. Because the task can be completed without calculations, it is considered to be conceptual according to our definition.

A passive approach with single-solution problem solving is common practice in engineering courses, despite evidence that it is less effective than an active approach with a conceptual focus. Changing faculty practices is challenging, and change efforts can be informed by frameworks that consider the process of adoption of a new idea or approach.

Adoption of Change

Multiple theoretical approaches provide insights into the change-adoption process, including diffusion of innovation (Rogers 2003), the concerns-based adoption model (Hall and Hord 2006), the culture of higher education, and the effect on individual change (Godfrey 2003). Two themes that are influential to faculty change cut across these approaches: social networks and beliefs about the importance of change.

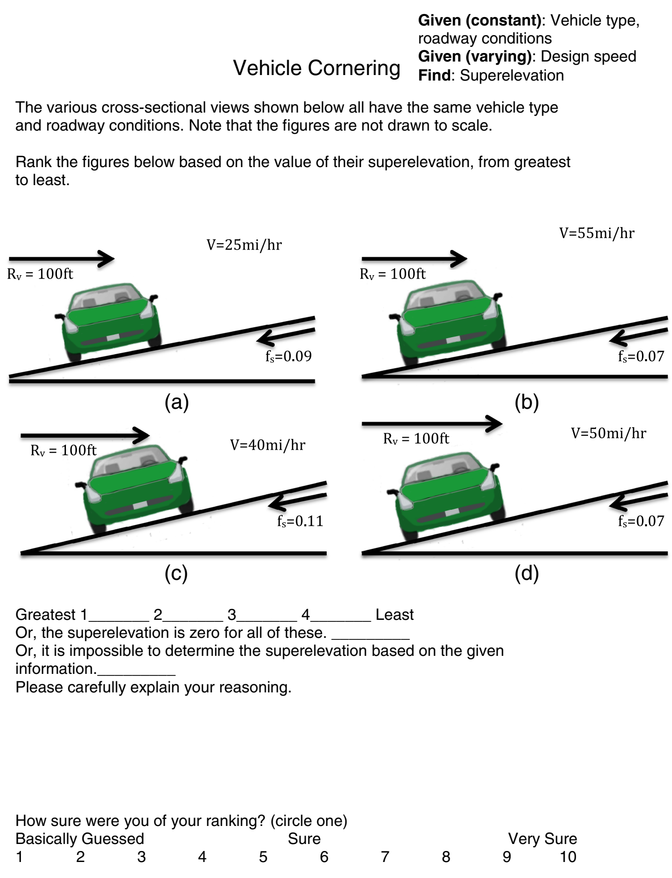


Fig. 2. Example ranking task on super elevation

Social capital consists of resources embedded in social networks that are available to members of that network (Lin 2001). Social networks are a core component of change because connections with individuals can serve educational purposes (to know more about an innovation), resource purposes (to have access to materials from others), and support purposes [to be part of a community of practice that shares the same goals and vision (Wenger and Snyder 2000)]. In our work, individuals' networks were assessed specifically regarding the sharing or codevelopment of curricular materials for their transportation engineering courses; we refer to this as a curriculum-development network.

Faculty beliefs about the importance of educational innovations are an important component of the change process. "Results of studies . . . imply that the way teachers adapt or adopt new practices in their classrooms relates to whether their beliefs match the assumptions inherent in the new programs or methods" (Richardson et al. 1991). In several studies, the level of importance educators attribute to an innovation correlates with whether they adopt this innovation. For example, Thompson (1984) reports that, "Teachers develop patterns of behavior that are characteristic of their instructional practice." In some cases, these patterns may be manifestations of consciously held notions, beliefs, and preferences that act as driving forces in shaping teachers' behavior. In other cases, the driving forces may have evolved out of the teacher's experience." Sparks (1988) concurs that ". . . teachers who saw these practices as important were more likely to use them."

TEEW Objectives

The agenda and assessment for the TEEW were shaped by the literature described in previous sections. We seek to facilitate the development of a common vision and a curriculum-development network, which will encourage the increased and enhanced implementation of active-learning strategies through the workshop and follow-up activities. At the TEEW, we attempted to provide a compelling body of evidence that active-learning environments are effective for student learning, and we provided multiple pathways for faculty to implement active learning in the classroom. We measured the workshop's effectiveness by investigating changes in beliefs about the importance of active learning using conceptual assessments, curriculum-development networks, and value of the workshop to participants.

The following objectives were established to determine the effect of the TEEW on shifts in faculty beliefs toward active learning and conceptual-assessment exercises, in the density and connectivity of the curriculum-development network, and in reported classroom practice:

1. Change the beliefs of transportation engineering educators regarding the importance of active learning and conceptual-assessment exercises in the introduction to transportation engineering class,
2. Contribute to the development of a curriculum-development network of transportation engineering educators committed to the collaborative development of improved educational resources for the introduction to transportation engineering class, and
3. Increase the use of active learning and conceptual assessment by transportation engineering educators in the introduction to transportation engineering class.

Active-learning exercises are defined broadly as any classroom engagement that is not passive (i.e., merely listening to a professor speak and taking notes). These exercises might include groups of students working together facilitated by the instructor, described as interactive by Chi (2009), or exercises representing a difficulty beyond those previously encountered in class, described as constructive by Chi (2009). For the purposes of this work, we do not include Chi's lowest level of active learning. Conceptual-assessment exercises are defined as any classroom engagement in which students are not tasked with the direct application of equations and the calculation of solutions; that is, they are required to describe the idea in words or pictures.

Methodology

To test our hypothesis that a well-designed workshop would affect positive changes in participants' beliefs, practices, and networks, we recruited a diverse group of participants, developed and executed a compelling and highly interactive two-day conference and workshop, and developed and administered a presurvey, postsurvey, and follow-up survey.

Participant Demographics and Recruitment

Facilitated group activities were a central element of the TEEW, so it was particularly important to ensure a diverse group of conference participants. The demographic elements considered when selecting participants included school type (public, private, community colleges, and 4-year B.S.-, M.S.-, and/or Ph.D.-granting institutions), faculty rank (adjunct faculty members, instructors, and tenured/tenure-track assistant, associate, and full professors), instruction experience, geography (Pacific, Mountain, Central, and Eastern Time Zones), gender, and race/ethnicity. The 60 conference participants (46 engineering faculty members, 5 public-sector employees, and 9 Ph.D. students) were distributed from across the United States (Fig. 3).

Participants were recruited actively by the conference organizing committee both personally and through advertisements distributed on numerous list serves, including the civil engineering department heads list serve.

Activities

The TEEW activities were designed around the following two themes: (1) the provision of evidence by nationally recognized experts supporting the efficacy of active and conceptual learning, and (2) the opportunity to collaboratively apply the new knowledge acquired. The presentations were intentionally short to keep the energy levels of the participants high and to maintain our focus on participants actively engaging in the content.

For example, one collaborative activity included a group of participants brainstorming the development of a ranking task considering the required sample size for spot speed observations. In this activity, a group of 6 participants was given a broad area of interest (traffic operations in the introduction to transportation engineering class), and then was tasked with selecting a concept and developing an outline for at least one ranking task dealing with that concept. At this stage in the workshop, ideas of context (how the idea is situated and presented) and confoundedness (interrelatedness and complexity) were not yet considered. The brainstorming work of the faculty groups was recorded by hand on large pads of paper, which were digitized and transcribed into Word files for dissemination to all conference participants and other interested parties through the NTCP website (http://nationaltransportationcurriculumproject.wordpress.com/). Additionally, dissemination of the materials developed at the TEEW took place through the Institute of Transport Engineers (ITE) Education Council in the form of presentations at the mid-year and annual meetings, newsletter articles, and in a presentation and conference paper presented at the 2013 American Society for Engineering Education (ASEE) annual meeting (Sanford Bernhardt et al. 2013).

The workshop resulted in the collaborative development of 108 draft learning activities and ranking tasks, 60 of which have

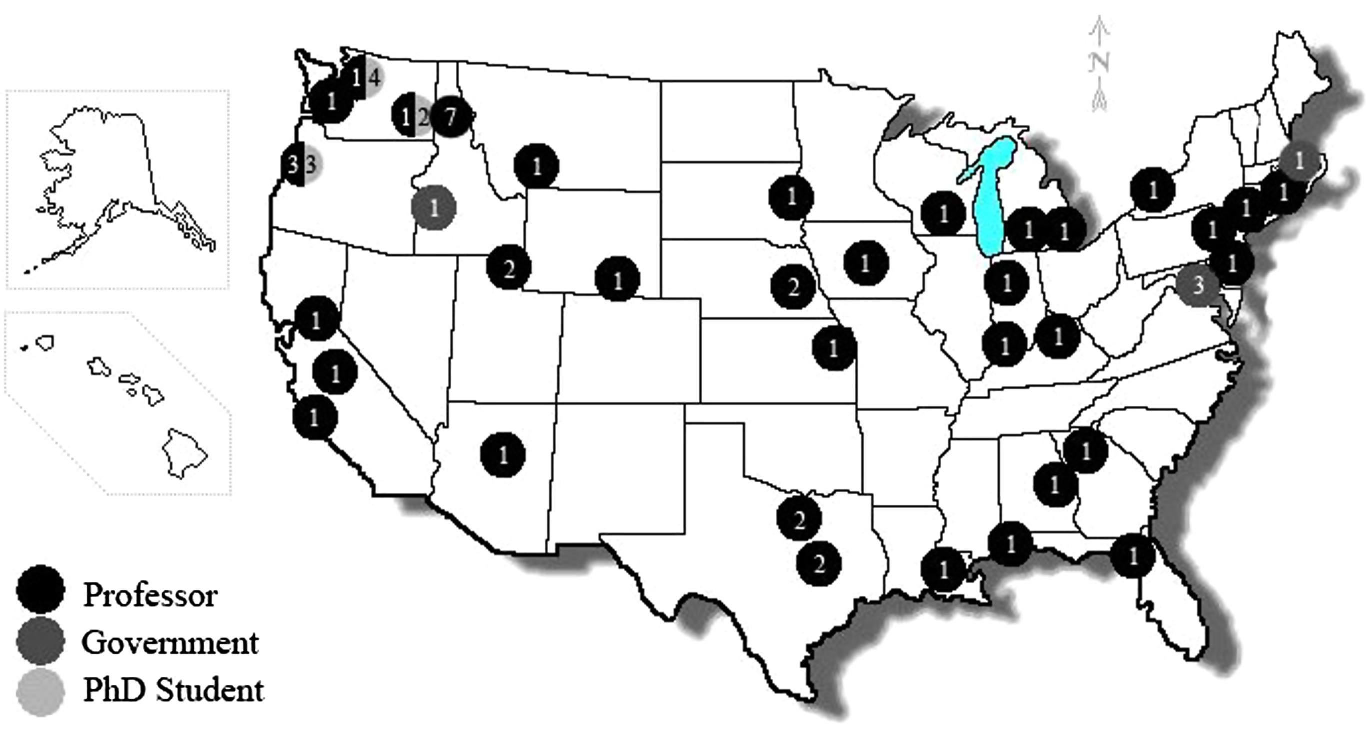


Fig. 3. Transportation engineering education workshop participants

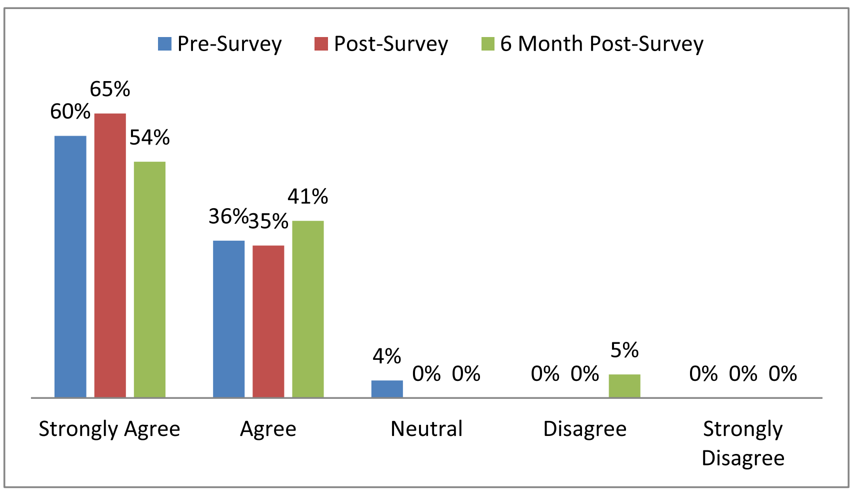
Table 1. Categories of Questions Included on Each Participant Survey

Categories/number of questions asked	Survey type/number of respondents		
	Presurvey/50	Postsurvey/43	Follow-up/37
Beliefs about active learning and conceptual assessment exercises/6	X	X	X
Active learning is an important part of a lecture period			
Conceptual exercises are an important part of a lecture period			
Active learning improves student understanding			
Conceptual exercises improve student understanding			
All instructors should implement active learning in their lecture			
All instructors should implement conceptual exercises in their lecture			
Engagement in curriculum-development networks/2	X	—	X
Value of workshop/2	—	—	X
What were the three most valuable aspects of the conference?			
What was the most influential aspect of the conference?			

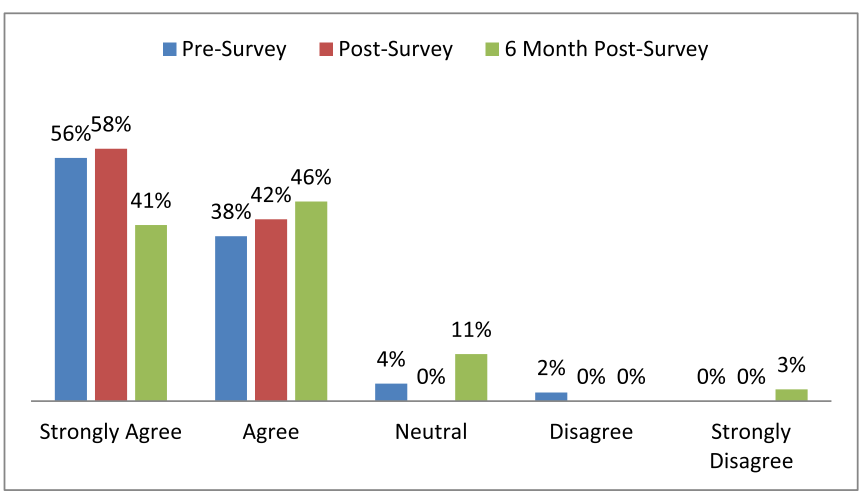
been digitized and refined. These 60 activities include traffic-operations topics such as the fundamental diagram of traffic flow, time-space diagrams, cycle length, and delay, and design topics such as stopping-sight distance on isolated vertical and horizontal curves, the alignment of horizontal curves in sequence, and vehicle cornering. Additionally, the workshop can serve as a model for dissemination and adoption of best transportation engineering teaching practices and materials moving forward (Sanford Bernhardt et al. 2013).

Evaluation

To measure the effect of the TEEW on conference participants, three surveys were developed and administered in sequence.



(a)



(b)

Fig. 4. Changes in participant beliefs that active learning and conceptual exercises are an important part of a lecture period: (a) active-learning exercises; (b) conceptual exercises

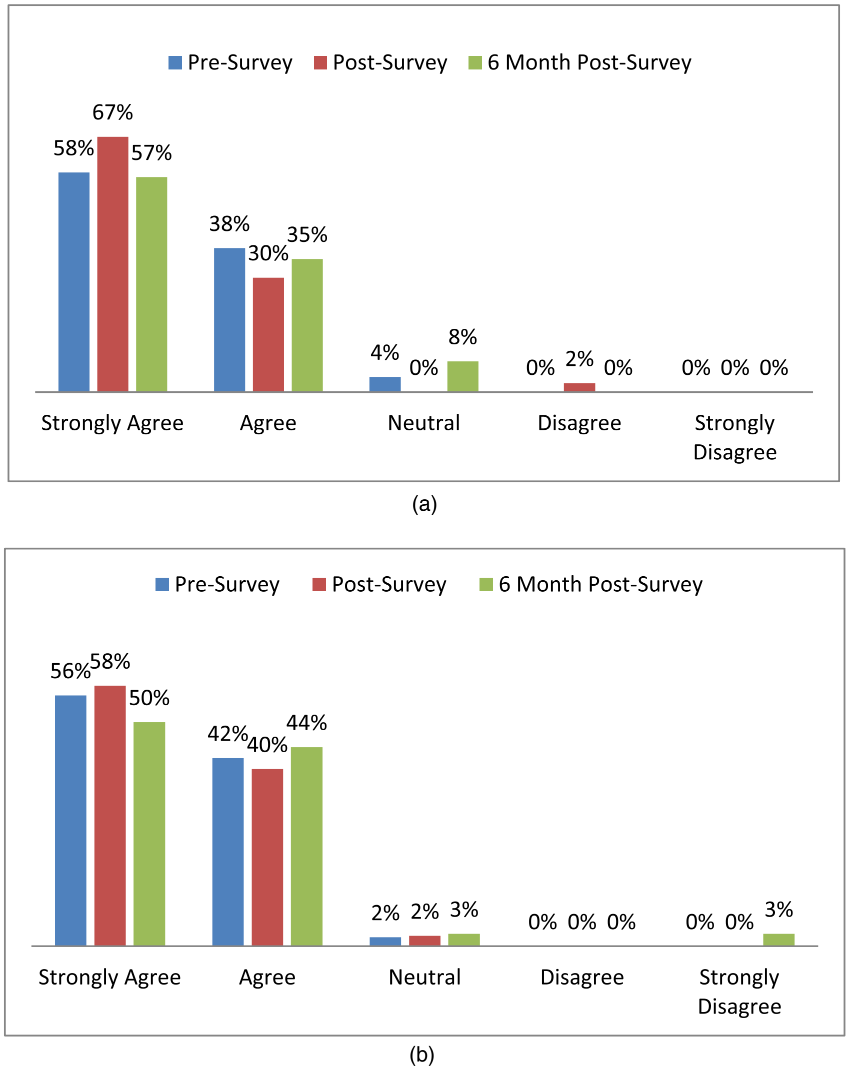


Fig. 5. Changes in participant beliefs that active learning and conceptual exercises improve student understanding: (a) active-learning exercises; (b) conceptual exercises

The presurvey took place as the initial activity on day one of the conference, the postsurvey took place as the last activity on day two of the conference, and the follow-up survey was administered six months after the conference. The categories of questions included beliefs about active learning and conceptual-assessment exercises, engagement in the curriculum-development network, and qualitative open-ended questions about the value of the workshop structure (Table 1).

Despite extensive evidence of the value of active learning and the link between beliefs and practices, no survey scales were found on teacher beliefs about active learning. Development and implementation of these questions in our study is the first step in establishing the validity and reliability of the questions. Six belief questions were developed and are shown in Table 1. Belief items utilized a five-point Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree) accompanied by an open-ended text box where a justification could be added. Some evidence of validity was found in responses from the justification text box, as discussed in the results. Specifically, we found and analyzed evidence of respondents' interpretations of the questions. Belief survey questions were analyzed for reliability using the Cronbach alpha reliability test. Shifts in beliefs across all three surveys were analyzed with paired t and chi-squared tests.

Network data were collected by asking all participants to indicate whether they had codeveloped, given to, or received from curricular materials for all other conference participants. Network maps were developed with network nodes representing individuals and directional links representing the sharing of teaching materials. The shift in the curriculum-development networks was determined by percent changes in the inclusivity (number of points that are included within the various connected parts of the network) and connectivity (general level of linkage among the points in a graph) of the network from the pre- and follow-up survey.

Open-ended survey questions regarding the value of the conference and ways in which it influenced participants' practice are shown at the bottom of Table 1. Collecting qualitative data allows researchers to investigate and understand how participants interpreted and acquired value from the experience, and how and why their practices changed as a result (e.g., Creswell 1998; Patton 2002). Qualitative survey data were analyzed by developing codes that described the value that participants found in the conference, and counting the prevalence of these codes (Miles and Huberman 1994).

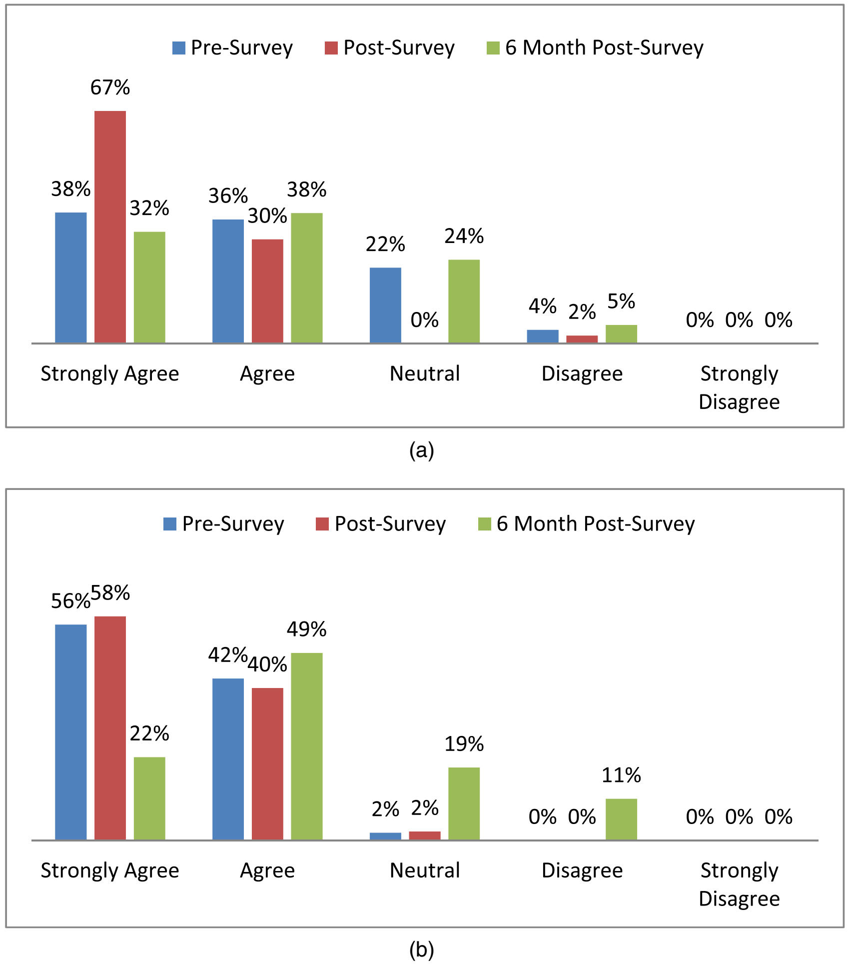


Fig. 6. Changes in participant beliefs that all instructors should implement active learning and conceptual exercises in their lectures: (a) active-learning exercises; (b) conceptual exercises

Results

The next sections detail the results for each of the categories, beliefs about active learning and conceptual-assessment exercises, engagement in curriculum-development networks, and the value of the workshop (Table 1).

Educational Beliefs

Responses to open-ended questions about active learning almost uniformly included text about students doing something other than listening; examples include "try out what they have learned," "engages students in the class," and provides opportunities for "learning by doing." Similarly, open-ended responses related to conceptual learning were generally focused on engagement with the concepts or ideas and not just calculating numbers. Example responses are "help students explain what the equation is," and "students be able to apply, not just regurgitate." These responses indicate that survey respondents interpreted this set of questions in reasonable alignment with our proposed definitions of active learning as students doing something other than listening and taking notes in the classroom, and conceptual exercise as focused on the concepts and not requiring calculations.

Figs. 4–6 show participant responses to the six belief questions. Generally, participants strongly agreed (range of 41–65%) or agreed (range of 35–46%) with the idea that active learning and conceptual-assessment exercises are an important part of lecture (Fig. 4). A similar pattern was observed in that participants strongly agreed (50–67%) or agreed (30–44%) with the idea that active learning and conceptual-assessment exercises improve student learning (Fig. 5).

Of the six belief questions, the extent of agreement with the notion that all instructors should implement active learning and conceptual exercises was the least consistent (Fig. 6). The majority of respondents again stated that they agreed or strongly agreed; however, compared to the other questions, a larger percentage of participants were neutral or even disagreed, particularly in the six-month follow-up survey.

The educational beliefs survey responses using the five-point Likert scale were transformed into numerical values with "strongly agree" responses given a value of 5 and "strongly disagree" responses given a value of 1. For the 57 participants who responded to one of the three surveys, 41 individuals completed the presurvey and postsurvey, 31 the presurvey and follow-up survey, and 24 completed all three surveys. Response rates provide meaningful evidence; however, the representativeness of the sample is more critical as we are interested in observing the responses across time. Even at our lowest response rate of 40%, we are confident that the sample reflects the population of participants.

Simple means and standard deviations for the paired and unpaired observations are shown in Table 2. Most of the participants strongly agreed with the statements in both the presurvey and

Table 2. Presurvey and Postsurvey Descriptive Statistics

Type	Descriptive statistic (sample size)	Question					
		1[a]	2[b]	3[c]	4[d]	5[e]	6[f]
Presurvey	Average (all observations, $n = 50$)	4.560	4.540	4.080	4.480	4.540	4.380
	Standard deviation (all observations, $n = 50$)	0.571	0.573	0.868	0.671	0.537	0.629
	Average (pre/post paired observations, $n = 41$)	4.512	4.512	3.927	4.439	4.512	4.317
	Standard deviation (pre/post paired observations, $n = 41$)	0.589	0.546	0.866	0.700	0.546	0.642
	Average (pre/follow-up paired observations, $n = 31$)	4.613	4.548	4.226	4.516	4.613	4.452
	Standard deviation (pre/follow-up paired observations, $n = 31$)	0.549	0.559	0.750	0.561	0.487	0.559
Postsurvey	Average (all observations, $n = 43$)	4.651	4.628	4.279	4.581	4.558	4.349
	Standard deviation (all observations, $n = 43$)	0.477	0.611	0.726	0.493	0.541	0.566
	Average (pre/post paired observations, $n = 41$)	4.659	4.634	4.268	4.561	4.561	4.341
	Standard deviation (pre/post paired observations, $n = 41$)	0.474	0.615	0.733	0.496	0.543	0.568
Follow-up survey	Average (all observations, $n = 37$)	4.432	4.486	3.973	4.216	4.389	3.811
	Standard deviation (all observations, $n = 37$)	0.755	0.642	0.885	0.843	0.792	0.896
	Average (pre/follow-up paired observations, $n = 31$)	4.360	4.440	3.800	4.120	4.400	3.680
	Standard deviation (pre/follow-up paired observations, $n = 31$)	0.686	0.637	0.894	0.909	0.566	0.882

[a]Active-learning exercises are an important part of lecture.
[b]Active-learning exercises improve student understanding.
[c]Active-learning exercises should be implemented by all instructors.
[d]Conceptual exercises are an important part of lecture.
[e]Conceptual exercises improve student understanding.
[f]Conceptual exercises should be implemented by all instructors.

postsurvey. Question 1 scored the highest in both the presurvey and postsurvey; for the follow-up survey, the question on whether active learning improves student understanding scored slightly higher.

When comparing the results of the presurvey and postsurvey, the responses were higher (i.e., more favorable) in the postsurvey compared to those of the presurvey in all cases except for question 6, which asked whether conceptual exercises should be implemented by all instructors. For question 6, the average was slightly lower when all observations were included and slightly higher when only the paired observations were analyzed. The standard deviations were lower for questions 1 (active-learning importance), 3 (active-learning implementation), 4 (conceptual-exercises importance), and 6 (conceptual-learning implementation), indicating greater consensus among the participants. There were very minor increases in standard deviation for questions 2 and 5.

We found different results when comparing the presurvey and follow-up survey. For all six questions, the numerical results were lower. The differences were slight for questions 1 (active-learning importance), 2 (active learning improves learning), and 5 (conceptual exercise improves learning). Questions 3 and 4 showed larger differences for both questions.

Table 3. Results of Statistical Analyses

Comparison of	Statistical tests	Question					
		1[a]	2[b]	3[c]	4[d]	5[e]	6[f]
Presurvey and postsurvey	Chi-square	0.195	0.147	0.152	0.396	**0.041**	0.168
	Paired t-test (p-values)	0.057	0.133	**0.005**	0.281	0.599	0.838
Presurvey and follow-up survey	Chi-square	0.335	0.352	0.491	0.412	**0.002**	**0.020**
	Paired t-test (p-values)	0.134	0.845	**0.023**	0.086	0.169	**0.003**

Note: The values shown in bold indicate differences that are statistically significant at the $\alpha = 0.05$ level.
[a]Active-learning exercises are an important part of lecture.
[b]Active-learning exercises improve student understanding.
[c]Active-learning exercises should be implemented by all instructors.
[d]Conceptual exercises are an important part of lecture.
[e]Conceptual exercises improve student understanding.
[f]Conceptual exercises should be implemented by all instructors.

To determine whether the differences shown in Table 2 are statistically significant, we performed both a chi-squared test and a paired t-test; Table 3 shows the resulting p-values. The chi-square test analyzed whether there were significant differences between the observed frequencies in the presurvey and postsurvey and the presurvey and follow-up survey, using the 24 observations where all three surveys were completed. Question 5 (conceptual exercises) was the only question that had a significant difference between the presurvey and postsurvey using the chi-squared statistical test. When comparing the presurvey and follow-up survey, question 5 was significant along with question 6 (conceptual-exercise implementation).

A second analysis was performed using the paired presurvey and postsurvey observations and a t-test statistic. Differences in responses to question 3 (active-learning implementation) were statistically significant, and question 1 (active-learning importance) was very close to the significance level of $\alpha = 0.05$ ($p = 0.057$). For the presurvey versus follow-up survey, question 3 was significant along with question 6 (conceptual-exercise implementation).

The survey questions as a whole were intended to measure participants' beliefs about the educational value of active and conceptual-learning exercises. To determine whether sets of questions constitute a scale (the questions are not independent, and are in fact different ways of asking the same question), the Cronbach alpha reliability coefficient was calculated for the three active-learning questions, the three conceptual-exercise questions, and all questions together for each of the three survey implementations (pre, post, and follow-up). The resulting values are shown in Table 4, and generally indicate that each set of three questions

Table 4. Cronbach Alpha Values for Survey Questions

Survey	Active-learning questions (3)	Conceptual-exercise questions (3)	All 6 questions
Presurvey	0.70	0.80	0.75
Postsurvey	0.71	0.85	0.82
Follow-up survey	0.70	0.71	0.84

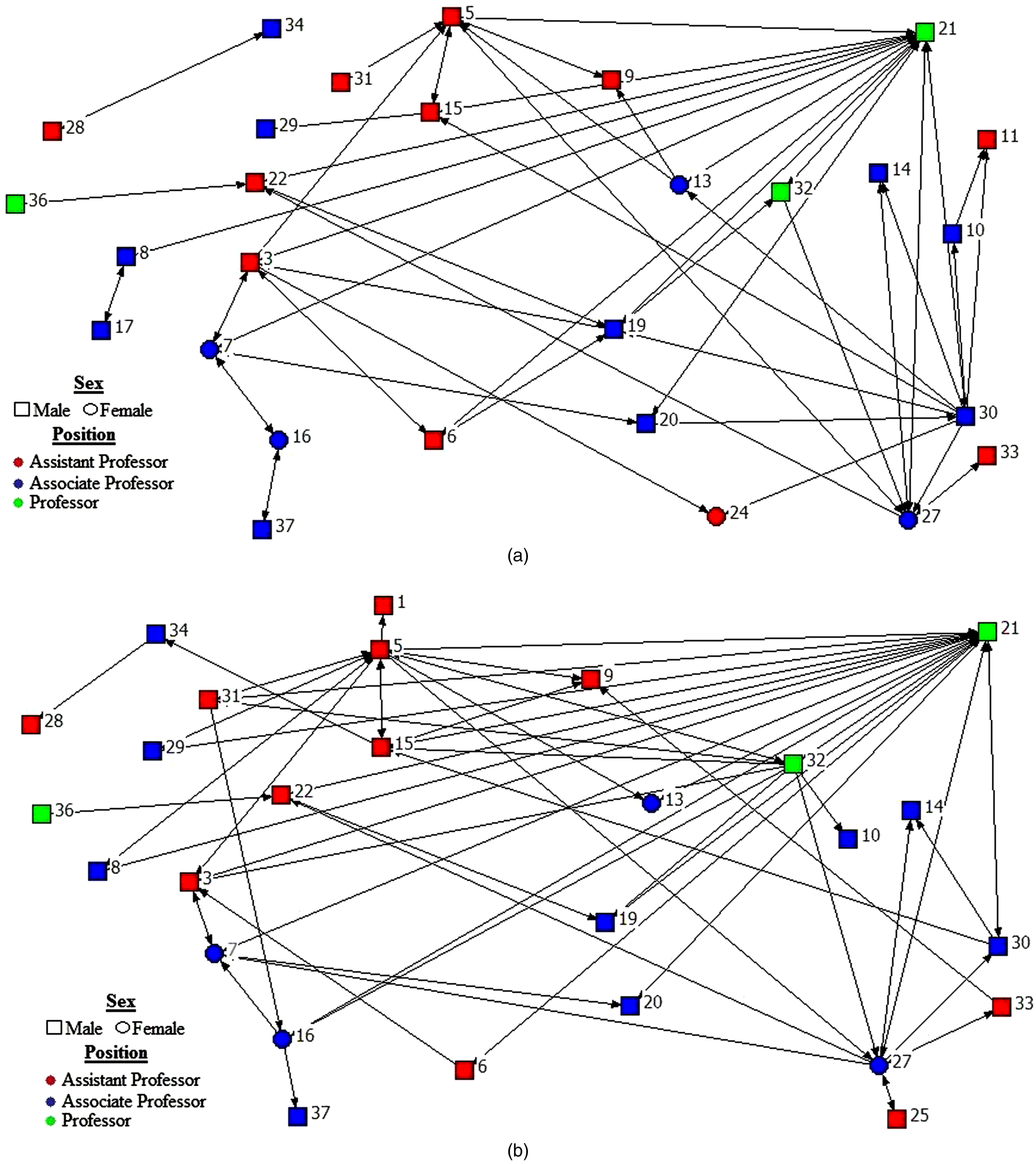


Fig. 7. Curriculum-development network among conference participants: (a) pre-existing network; (b) network six months later

and the six questions constitute a scale, considering all values are greater than 0.7 (Kline 1999). A new variable was calculated as an individual's average response to all six questions (Table 4, column 4), which represented the scale of the educational value of active learning and conceptual exercises.

Paired *t*-tests were conducted for three combinations using the new variable in the pairwise combinations of surveys (pre and post, pre and follow-up, and post and follow-up). The resulting *p*-values are 0.011, 0.013, and 0.0022, indicating that that there is a statistically significant difference in postsurvey and follow-up survey results. The *p*-values of slightly greater than 0.010 for pre and post and pre and follow-up surveys show that the differences were nearly statistically significant at the 0.01 significance level.

Curriculum-Development Networks

To better understand the effect of the TEEW on participants currently employed as faculty members, we performed social-network analysis. Each participant was asked in the presurvey and in the follow-up survey about sharing of curricular materials with other TEEW participants. UCINET 6, a software package for the analysis of social-network data (Borgatti et al. 2002), was used to develop a preexisting network figure based on 36 responses, and a six-month network figure based on 27 responses (Fig. 7). Each node in the figure represents an individual participant. The gender of the participant is documented as a square node (male) or a circular node (female). The rank of the participant is documented by three colors [red (assistant professor), blue (associate professor), and green (full

Table 5. Change in Network Density and Connectivity

Measures	Presurvey	Follow-up survey	Delta
Inclusiveness	0.76	1.0	0.24
Density	0.05	0.19	0.14

professor)]. The links represent a sharing of curriculum materials; an arrow pointing away from a node indicates that materials were provided by a participant, whereas an arrow pointing toward a node indicates that a participant received materials.

Two widely accepted quantitative measures, inclusiveness and network density, were used to further describe the change over time in the overall networks (Scott 2010). For our purposes, inclusiveness refers to the number of points that are included within the various connected parts of the network. This value can be calculated as the total number of nodes minus the number of isolated nodes [Eq. (1)] (Wasserman and Faust 2009).

$$\text{Inclusiveness} = \frac{(\text{Total number of nodes} - \text{Number of isolated nodes})}{\text{Total number of nodes}} \quad (1)$$

The network density describes the general level of linkage among the points in a graph. The more points that are connected to one another, the denser the graph. For a directed-network graph, where the data are asymmetrical, the network-density calculation can be expressed as a proportion of the maximum number of lines possible [Eq. (2)] (Wasserman and Faust 2009).

$$\text{Density} = \frac{l}{n(n-1)} \quad (2)$$

where l = number of lines, and n = number of nodes.

By calculating the inclusiveness and density of networks from the presurvey and follow-up survey and measuring the delta between the two, we can quantify whether a shift has occurred in the professional network (Table 5). The values in Table 5 correspond to a 24.0% increase in network inclusiveness and a 280.0% increase in network density.

Beyond the overall network analysis, the performance of an individual professor can be considered. This was accomplished by calculating the indegree (the number of professors giving a particular professor materials) and the outdegree (the number of professors that a particular professor provided materials to) for each node in the before and after network. The sum of the indegree and outdegree measures for each individual node ranged from 0 to 23 in both the before and after network. The highest observed vales in the before network were an indegree of 11 and an outdegree of 12. In the after network, the highest indegree was 7 and the highest outdegree was 16. The sum of the indegree and outdegree were calculated for each node; 35.1% of the nodes in the before network and 40.7% in the after network had sums greater than 5.

Value and Influence of Workshop

Participant responses to the question from the follow-up survey "What were the 3 most valuable aspects of the conference?" were coded, tabulated, and are shown in Table 6. The first two categories, representing approximately 55% of participants, relate to improved knowledge of active learning and conceptual exercises, and having the opportunity to develop activities and ranking tasks during the workshop. The last two categories relate to interacting with others during the conference, and developing networks to facilitate sharing of materials that extend beyond the duration of the workshop.

Table 6. Value of Participating in the Transportation Engineering Education Workshop

Category	Example quote	Percentage
Learning about active learning and conceptual exercises	"Learning how to develop / implement these types of exercises"	35
Developing material	"Working on ranking tasks"	20
Discussions and idea exchanges	"Hearing the approaches that others have taken in their classroom teaching"	20
Networking	"Networking, contacts with other similar thinking teachers"	25

Collectively, these responses suggest that the goals of the conference were met in the eyes of the participants; they learned more about both the value and mechanics of developing active conceptual exercises, and they established professional networks to continue the development and sharing process beyond the TEEW conference.

In the follow-up survey, participants were asked to describe the most influential aspect of the conference. Ninety percent of responses related to the influence on changing their teaching practices, including "providing the motivation to take the time to put more conceptual exercises in my classes," "given more inspiration to consider making radical changes to my course design," "I hope to implement ranking tasks in my classes," and "I am conscious of how little active learning I have in my lectures . . . my goal is to try and add either one more active learning or conceptual exercise to each lecture."

In the follow-up survey, faculty members were asked if they used and/or designed active and conceptual-learning exercises; 67% said they both designed and used new active-learning exercises, 52% said they designed new conceptual-learning exercises, and 65% said they used conceptual-learning exercises. Considered together, the quantitative and qualitative responses strongly indicate that participants are either in the process of or have already changed their teaching practices as a result of participating in the conference.

Summary and Conclusions

This research effort sought to determine whether facilitating collaborative development of active-learning activities and conceptual-assessment exercises through a thoughtfully designed workshop could positively influence beliefs about the importance of active and conceptual learning and sharing of curricular materials within a curriculum-development network. The TEEW attracted 60 participants, including faculty members, Ph.D. students, and public-sector employees. Meaningful shifts were identified across time in participant beliefs and the curriculum-development network.

- Most participants indicated a belief in the importance of active and conceptual learning in the classroom in the presurvey, postsurvey, and follow-up survey. It is not surprising that the largely self-selected participants were predisposed to value active and conceptual learning, and it is encouraging that approximately two-thirds of participants reported that they both designed and implemented new learning activities, and implemented new conceptual exercises. This suggests that participants' enthusiasm for active and conceptual learning was strengthened, making them more likely to expend the energy to implement such activities in the classroom.

- Participant beliefs that all instructors should implement active and conceptual learning activities in the classroom first increased (from immediately before to immediately after the workshop), then decreased (from immediately after to six-months later). This could reflect both the recognition that implementing these techniques in the real world is significantly more challenging than developing them in a supportive environment, and that this is something with which those who have not been trained may struggle. This also provides indirect evidence for the value of the curriculum-development network. It suggests that participants have developed a more nuanced understanding of the requirements for implementing such activities effectively.
- The six belief questions combined constitute a scale of questions measuring the educational value of active learning and conceptual exercises. Testing of this scale confirmed a statistically significant difference in postsurvey and follow-up survey results, and an approximately statistically significant difference in pre and postsurvey results and pre and follow-up survey results, indicating that when taken in the aggregate, the questions posed in the surveys did demonstrate shifts in beliefs. The self-selection of participants may have led to higher than average presurvey results, and the challenges associated with implementing new techniques in engineering classrooms may have depressed the follow-up survey results.
- The inclusiveness and density of the curriculum-development network increased by 24% and 280%, respectively. This suggests that participants substantially widened their networks of engineering education colleagues through the workshop.
- Conference participants reported that they learned more about the importance and development of active conceptual exercises and developed network ties to facilitate future development and implementation. Approximately 70% of respondents indicated that they had already designed and implemented active and conceptual exercises in their classrooms as a result of the conference. These open-ended and quantitative responses suggest that the workshop had the desired outcome of effecting change in transportation engineering classrooms.

These data and the associated analysis should help to inform current efforts to coordinate professional development workshops for engineering faculty and to encourage the implementation of active learning and conceptual exercises in the classroom. Although direct causal links are not established between the workshop and the desired result of faculty adopting educational innovation in their classrooms, strong preliminary evidence is presented to suggest that the professional development workshop model described in this research did contribute to positive improvements in faculty beliefs, curriculum-development networks, and classroom practice.

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