# A Model for Collaborative Curriculum Design in Transportation Engineering Education

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## Abstract

The National Transportation Curriculum Project (NTCP) has been underway for four years as an ad-hoc, collaborative effort to effect changes in transportation engineering education. Specifically, the NTCP had developed a set of learning outcomes and associated knowledge tables for the introductory transportation engineering course that is taught in most civil engineering programs, and most recently the project led a workshop, supported by the National Science Foundation, in which approximately 60 participants developed learning and assessment activities to support these learning outcomes. The inter-generational, geographically and institutionally diverse group of faculty members that form the core project group provide a model for cross-institutional collaborative curriculum design.


## Introduction

The National Transportation Curriculum Project (NTCP) began as an effort by a small group of transportation engineering educators to continue the momentum generated by the 2009 Transportation Education Conference (http://www.webs1.uidaho.edu/transportation_education_conference-2009/index.htm). The 2009 conference focused on how to 1) map the learning domain for transportation engineering, 2) create active learning environments for undergraduate transportation engineering students, and 3) develop collaborative tools for sharing transportation engineering curricular materials. The NTCP has focused on how to improve the typical introductory transportation course taught in most civil engineering programs and how to effect positive change at institutions across the U.S. Using backwards course design (beginning with desired outcomes and working "backwards" to learning objectives and activities), NTCP members have collaboratively developed learning outcomes and knowledge tables for the introductory transportation course. These products have been presented to and discussed by educators and practitioners at meetings of the American Society for Engineering Education, the Institute of Transportation Engineers (ITE), and the Transportation Research Board (TRB), and revised in response to this feedback.

Most recently, project members convened a Transportation Engineering Educators Workshop, sponsored by the National Science Foundation, at which approximately 60 participants worked in teams to develop ranking tasks and other learning activities based on the NTCP learning outcomes and knowledge tables. Teams focused on transportation planning, design, operations, and safety and developed networks of educators with similar interests. Ongoing assessment of the workshop itself is examining perceptions of participants with regard to the importance of and willingness to use such activities, as well as the development of peer networks for developing and sharing resources and the workshop's role in the larger collaborative curriculum design effort.

This paper describes a model for collaborative curriculum design that could be applied to any engineering discipline. The paper begins with a review of related work. This is followed by a description of the goals of the National Transportation Curriculum Project and motivating factors specific to transportation education. Next, the paper explains how the project has developed collaboratively and presents examples of the products to date. The subsequent section connects the NTCP experiences to the larger conversation and presents a model for collaborative curriculum development in any discipline. Finally, the paper assesses the results of the NTCP to date, provides suggestions for others wanting to undertake such an effort, and describes the next steps for the NTCP.

**Collaborative Curriculum Development**

While several faculty members may teach a course over a period of several semesters, most civil engineering courses are the responsibility of a single faculty member in a particular semester. Depending on the placement of the course in the curriculum – whether it is a required or an elective course, whether it is a pre-requisite for other courses, etc. – the faculty member may not be required, and may have little need, to consult with colleagues on the course objectives or other aspects of the course. Depending on the size and nature of the department, a faculty member may be the only person in the department with expertise in the course subject, or s/he may be one of several colleagues who teach in the sub-discipline. In the latter case, faculty members may discuss their courses with colleagues, and in fact, several of them may teach the course and want to standardize it to some degree. However, in our experience it is uncommon for faculty to collaborate on courses across institutional boundaries.

One such cross-institutional effort was undertaken in the area of civil infrastructure management education. Four faculty members worked with a course that one had designed and in which the other three had been students. The initial course was adapted at three additional institutions, and new ideas were fed back through the network to change all four courses in institution-appropriate ways.[1] Subsequently, three of the collaborators examined the effectiveness of the learning activities in the courses in terms of increasing student interest in the subject matter and effecting student learning.[2]

In a related effort, also in the field of civil infrastructure management, an ad-hoc group of faculty members from the U.S. and Canada established the Infrastructure Management Research and Education Workshop series (IMRE) with the goals of building a network and leveraging the connections to improve education and research collaborations.[3] The most substantial outcomes of the IMRE workshops have been the Annual Inter-university Symposium on Infrastructure Management (AISIM), a two-day graduate research symposium held each summer, and a bi-annual Infrastructure Management Boot Camp taught by volunteer faculty from a variety of institutions and in which graduate students enroll and receive course credit. The former builds community and provides students with a chance to have their work critically reviewed by accompanying faculty judges, and the latter provides access to advanced coursework for which the expertise may not exist at the students' home institutions.

The literature cited above describes bottom-up efforts by faculty members to reach across institutional boundaries to improve student experiences (primarily for graduate students) in a narrow sub-discipline. Borrego et al.[4] surveyed engineering department heads to determine the extent to which faculty members are aware of engineering education innovations that transcend disciplinary boundaries, and the extent to which such innovations are adopted across institutions. Further, they sought to understand what factors affected the extent of awareness and adoption. Their literature review notes that "the primary change strategy [with regard to engineering education] has been to develop and disseminate pedagogies and curricula" rather than to focus on faculty development. They go on to discuss the importance of networks for diffusion of change.

One of the education innovations in which Borrego et al.[4] were particularly interested is "student active pedagogies," or active learning. Their definition, based on an extensive review of the literature, is:

> Students are actively engaged with course material in the classroom. Examples of active classroom engagement include: performing mini-experiments in the classroom and interpreting results, working in pairs or groups to address questions about the material, and working in pairs or groups to answer problems or challenges that have been posed by the instructor.

Borrego et al.[4] also note, citing their literature review, that the decision to implement active learning can be made independently by a course instructor and that it can be influenced by peer networks.

Another innovative approach to improving student learning is the concept of "backwards course design."[5] Historically, educators often focused on the day-to-day activities in a classroom to facilitate learning about particular concepts. In the backwards course design paradigm, this is turned on its head, and the course designer instead begins with envisioning the overall outcomes for the end of the course and beyond. That is, the starting point is "What should students know and be able to do at the completion of this course?" and the course activities are designed to support these objectives.

Collaborative curriculum development addresses the often conflicting issues of learning effectiveness and adoption simultaneously. Many curriculum development efforts assume that an approach can be developed in one location, the impact of the curriculum tested, and this innovation transferred to other locations. And, as long as fidelity is achieved, or more loosely speaking, consistency across implementation, then it will be effective. Some of the current trends in National Science Foundation programs provide evidence that this approach isn't working. For example, the NSF WIDER program is focused on single institution reform of undergraduate STEM programs, and, instead of imposing specific ideas and ways of teaching the focus instead is on changing the general approach to teaching and learning. This approach is well-founded on theories of adoption and institutional change[6-8], which suggest that faculty's decisions to change their practice are individualized, largely influenced by the culture in which they participate. Additionally, the implementation of curriculum is personalized. In other words, there is no such thing as pure fidelity in implementation; it is possible that an individual could take curriculum and a pedagogical approach proven to be effective in one setting and implement it in a way that is very ineffective. Our collaborative curriculum development approach addresses this conflict of effectiveness and adoptability by providing general ideas or frameworks for development, while simultaneously allowing for faculty to develop their own personalized approaches within boundaries that have previously shown to be effective.

**National Transportation Curriculum Project**

The goal of the National Transportation Curriculum Project (NTCP) is to improve transportation engineering education. So far, the NTCP has focused at the undergraduate level and specifically on the typical introductory transportation engineering course that is required of most civil engineering majors. Further, the project has combined educational innovation and dissemination in an effort to engage a broad group of stakeholders in development as well as adoption of materials. The current focus is on implementation of active learning and conceptual assessments by a large network of transportation faculty members. Project success is a network of professionals who are committed to undergraduate transportation engineering education in the context of the civil engineering curriculum and, ultimately, improving the transportation education of undergraduate civil engineers.

Figure 1 shows a working version of the NTCP mission. The collaboration is represented by both the inputs (e.g. the knowledge and relationships of participants) and outputs (e.g. workshops reaching a variety of stakeholders), and the impacts of the collaboration are reflected in the outcomes.

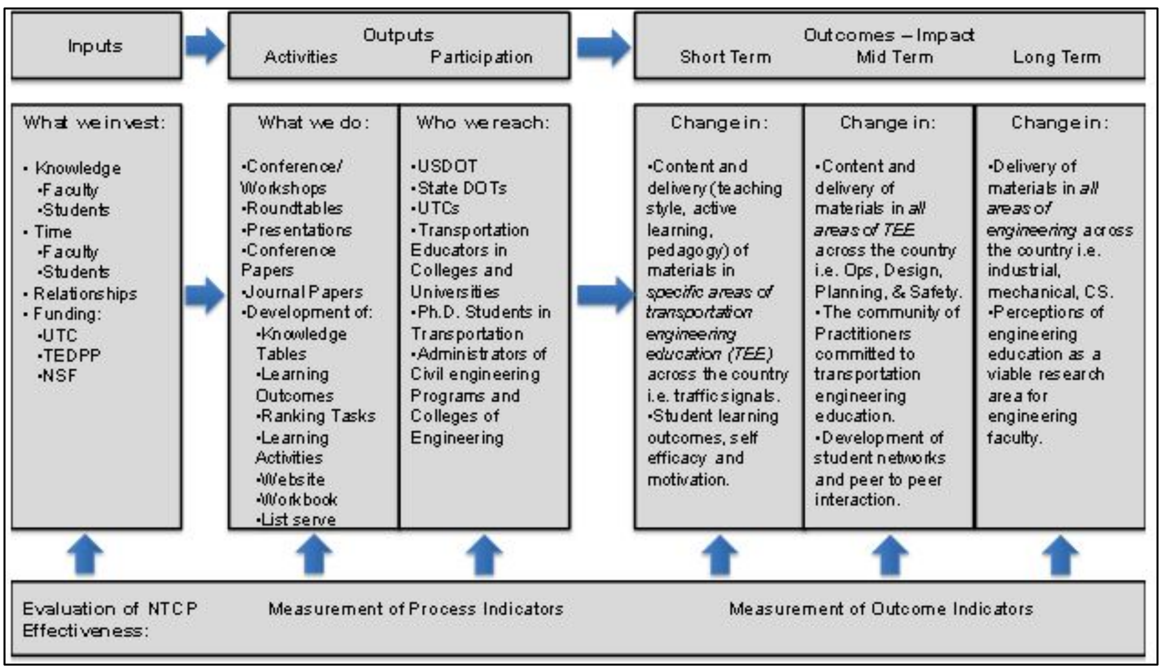



Figure 1. National Transportation Curriculum Project Mission.

The National Transportation Curriculum Project was initiated at the conclusion of the 2009 Transportation Engineering Educators Conference. Both the conference and the NTCP members were motivated by the pedagogical and professional challenges of recruiting, educating, and retaining students in the transportation profession.[9] More specifically, concerns that the typical introductory transportation engineering course does not meet the needs of students or the profession as well as it might prompted the NTCP to focus on that course. Within the course, NTCP members were particularly interested in moving students from lower to higher levels in Bloom's Taxonomy.[10] Because the course is often a broad survey of many of the areas within transportation engineering, it can seem to focus more on recall than on deeper conceptual learning. From the outset, NTCP members hypothesized that a collaborative approach would be more likely to lead to larger impacts in a shorter time than would be possible if members were working individually within their own institutions. Using the previously described model of backward course design, the project has

- developed suggested course learning outcomes and associated knowledge tables that provide a framework for instructors to employ in developing and revising such courses,
- educated faculty about the importance of active learning techniques in transportation engineering, and
- facilitated the development of learning and assessment activities based on the learning outcomes and knowledge tables developed.

Table 1 shows a set of learning outcomes developed for the course by the NTCP. As explained by Young et al.[11], the competencies listed in the first column are the core course learning outcomes. The remaining columns refer to increasingly more integrated use of the knowledge from the course learning outcomes both within the introductory course and subsequently. These learning outcomes went through several cycles of development, feedback, and revision by a broad set of stakeholders, including practitioners as well as faculty members. The supporting knowledge tables were developed through a similar process, and each effort was led someone with expertise in that sub-discipline. The knowledge tables take the outcomes listed in Table 1 and provide details to help a faculty member design a course to achieve the outcomes. More details about the approach and results from these tasks can be found in articles by Beyerlein et al.[12], Sanford Bernhardt et al.[13], and Bill et al.[14]; and the knowledge tables also are available on the project website (http://nationaltransportationcurriculumproject.wordpress.com/home/knowledge-tables/). The collaborative approach to development of the learning outcomes and knowledge tables ensured that a wide range of sub-disciplinary expertise would be represented. Once the learning outcomes were drafted, the knowledge tables were constructed and reviewed by smaller teams of experts in those sub-disciplines. The variety of views represented form the project's inception facilitated the broader feedback from stakeholders in the professional community.

NTCP members agreed early in the process that it would be critical to get feedback early and often from a variety of constituents. These efforts have included faculty members, professionals in industry and government, and graduate students. In addition to many informal interaction and the 2012 NSF-sponsored workshop, project members have interacted formally with stakeholders in venues such as:

- American Society for Engineering Education: 2010, 2011, and 2012 ASEE papers/presentations;
- Institute of Transportation Engineers: 2011 conversation circle
- Transportation Research Board: 2010 workshop; 2010 and 2011 papers/presentations

These learning outcomes and knowledge tables were piloted at three institutions as guides for revising the introductory transportation engineering course. The three courses were assessed using a mixed methods evaluation; this is documented in Young et al.[11]. In the pilot implementations, results of surveys of student perceptions were inconclusive. Development of a library of learning activities was identified as an opportunity to improve the efficacy with which the learning outcomes could be achieved.

Table 1. Suggested Learning Outcomes for the Introductory Transportation Course[15]

| 1. Competencies | 2. Movement | 3. Experience | 4. Integrated Performance |
|---|---|---|---|
| 1.1 Complete a geometric design for a section of a transportation facility.<br>1.2 Complete level of service analysis for basic freeway segment.<br>1.3 Complete signal timing design for fixed time isolated intersection.<br>1.4 Design and conduct a safety analysis<br>1.5 Forecast demand for a transportation system<br>1.6 Explain pavement design referring to standard design and procedures. | 2.1 Able to apply the scientific method to transportation problems.<br>2.2 Able to explain relationship between components of the transportation delivery process and appreciate how course content supports these relationships.<br>2.3 Increased ability to connect theory with field observations and ability to identify limitations in theory/models | 3.1 Connecting driving and pedestrian experiences with transportation terminology and common/classic transportation engineering problems (i.e. safety, congestion, energy, and the environment).<br>3.2 Heightened awareness of the global transportation system that connects producers and consumers | 4.1 Integration of design, operations, and planning concepts to create a traffic impact analysis project.<br>4.2 Integration of complete streets principles in planning, design, and operations of a transportation system |

The 2012 Transportation Engineering Educators Conference/Workshop, sponsored by the National Science Foundation, brought together approximately 60 faculty members to develop a level of comfort with active learning as a pedagogical approach, develop learning and assessment activities for the introductory transportation engineering course, and form collegial networks to promote further development, sharing, and adoption of materials. Figure 2 shows the geographic distribution of workshop participants.

The overarching goals of the workshop were to provide transportation faculty with 1) a compelling and engaging experience where they could be exposed to a body of evidence to suggest that active learning is effective, and 2) an opportunity to develop relatively simple materials and strategies to implement active learning in the introduction to transportation engineering classroom. The desired outcome from this effort was increased implementation of active learning in transportation engineering classes by workshop participants. Pre- and post-surveys were administered to assess changes in participant beliefs related to active learning and conceptual exercises. Specifically, participants were asked to respond to statements that 1) active learning and conceptual exercises are an important part of lecture, 2) active learning and conceptual exercises improve student understanding, and 3) all instructors should implement active learning and conceptual exercises in their lectures. The conference organizers propose that if faculty members could increase their agreement with these statements, they would be more likely to adopt active learning and conceptual exercises in their classrooms. The general trend of increased agreement with the statements after the conclusion of the conference suggests that the actives of the conference did shift participant beliefs regarding active learning and conceptual exercises.

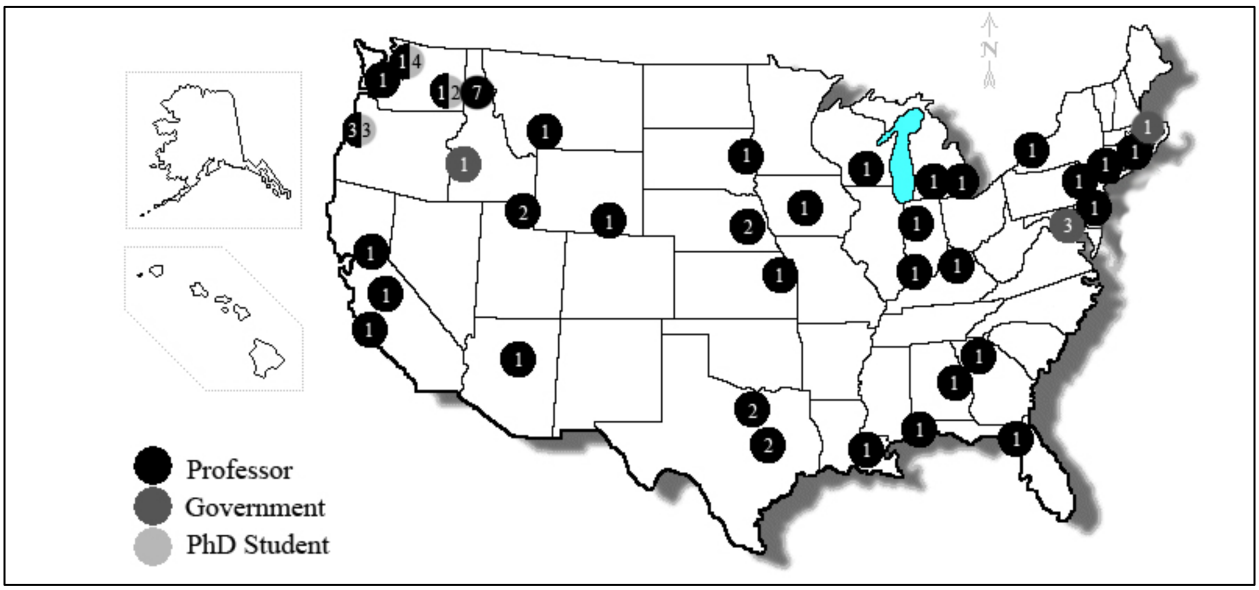
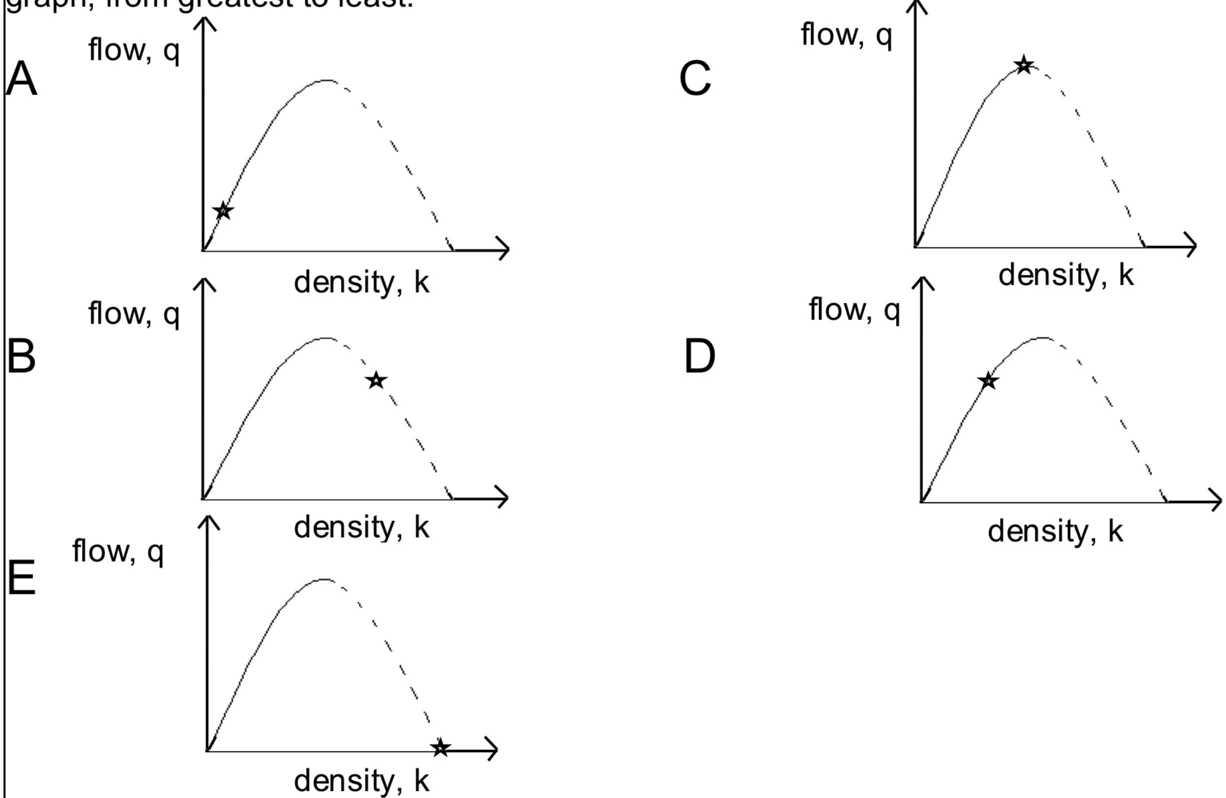



Figure 2. Geographic distribution of workshop participants.

The workshop was organized with mini-lectures interspersed between working sessions in which participants applied their new knowledge – for example, after learning about ranking tasks, small groups of participants developed ranking tasks for domain concepts about which they have expertise. During the workshop, participants created drafts for 108 ranking tasks and other learning activities based on the NTCP learning outcomes and knowledge tables. To date, these drafts have led to 60 “polished” ranking tasks that have been developed using a standard template. These ranking tasks include content on the fundamental speed-flow-density diagram, time-space diagrams, traffic signal cycle length and delay, isolated vertical and horizontal curve stopping sight distance, safety data, and other topics. Figure 3 shows an example of one of the ranking tasks begun at the workshop; development of other ranking tasks continues, and those that have been formatted and vetted to date are available on the project website and summarized at http://nationaltransportationcurriculumproject.wordpress.com/home/nsf-workshop/summary-of-developed-conference-materials-10-25-12/.

The following figures represent the fundamental diagram of traffic flow, that describe the relationship between density (veh/mi) and corresponding flow of traffic (veh/hr). Features held constant for all figures are noted here, as well as the units being used.

Rank the figures based upon the speed (mi/hr) at the marked point (☆) of the graph, from greatest to least.




Greatest 1_______ 2_______ 3_______ 4_______ 5_______ Least *(Modify the number of spaces if the number of figures is different)*

Or, the speed is the same for all of these. _________
Or, it is not possible to determine the speed for all of these. _________
Please carefully explain your reasoning.

How sure were you of your ranking? (circle one)

| Basically Guessed | | | | Sure | | | | Very Sure | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Figure 3. Example Ranking Task

Workshop participants were surveyed about their level of connection with other workshop participants prior to the workshop, and follow-up surveys are being conducted to see how this network has changed subsequent to the workshop. It is anticipated that existing connections will be strengthened and that many new connections will have ben developed. As described by Borrego et al.[4], these networks are most important in promoting adoption of educational change by individual faculty members.

**Collaborative Development Model**

In reflecting on the progress of the NTCP to date, members' experiences as faculty members, and the literature, attributes related both to process and products that have been identified as important to the project's achievements. These attributes pertain to the collaborative methods by which the working group has operated and the products of the group's efforts. For example, the group has identified and created opportunities to further the quality of transportation engineering education, such as documentation of core concepts, knowledge tables, and learning outcomes, and then followed these efforts with the NSF-funded educators' workshop last year led by this group. An example of products from these efforts are the teaching tools developed at the workshop, such as active learning tools and the ranking tasks described previously, which have been developed with input from the larger community of educators working in this field. Further, we hypothesize that the following set of elements related to core personnel, communication, and products are likely to lead to success for others, where success is defined as developing a professional network and improving education of the target audience. Each category is discussed in terms of the experiences of the NTCP; recommendations for replicating the model in other disciplines are summarized in the paper's concluding section.

*Core Personnel*

The core project participants have been faculty members who self-selected at the conclusion of the initial workshop in Portland in 2009. All have intrinsic motivation – not only do all members care about workforce development and the future of the profession, all teach the course and would like to share best practices to make it better and discover new and innovative approaches to improving student learning. Team members volunteered to become involved, and this dual motivation has kept eight busy faculty members engaged in the project over a four-year period. The core group met at the 2009 Transportation Education Conference and developed from a working group formed in the final conference session. Within the first few months some of the original working group members moved to focus on other interests and additional members asked to participate. Since then, there has been minimal movement in and out of this core group over the four years, which has led to a strong sense of community within the group. Leadership of the project has been fluid as participants have transitioned into and out of leadership for particular aspects of the project.

Members of the core group represent all faculty ranks, all geographic regions of the U.S., a variety of institutional types, and a variety of sub-discipline specialties. This diversity of participation has been critical because to accomplish its goals, the project must reach across rank, institutional type, region, and specialty. The regional and institutional diversity is important because of the variety of institutional missions across the U.S. A group of core personnel that has subject matter expertise spanning the subject field (e.g., transportation engineering in this case) is important to ensure the full range of topics that would be expected by stakeholders in the field is addressed.

All products have had one or more champions within the core group. NTCP members have strategically published and presented ongoing and completed work both to get buy-in and improve the work, as described above, and to ensure that core faculty are being recognized at their own institutions for their work.

The size of the team matters as well. If a team is too small, it is not possible to achieve the participant diversity discussed in the previous paragraph. If it is too large, team members may not be as invested or be willing to take responsibility for particular tasks or products. For this initiative, a core team of between eight and ten people has functioned on the border of providing enough diversity and person-power while not allowing anyone to hide. Further, the number of core personnel directly affects communication strategies.

*Communication*

Ensuring good communication is important both within the team and with external stakeholders.

As described, the core team members are geographically diverse. It has been essential that core members communicate regularly. Over the past four years, the team has communicated via conference calls and online virtual meetings an average of 1-2 times per month, as needed. Core personnel also have taken advantage of opportunities to meet face-to-face in conjunction with related activities, such as the Annual Meeting of the Transportation Research Bard or the Institute of Transportation Engineers' Annual Meeting, even if not all members can attend. This regular communication has been vital to building the team dynamics and keeping project momentum going. Meeting organization responsibilities have rotated; at the end of each meeting someone volunteers to organize the next, and this is most often the person who is leading the current effort.

An initial challenge was to establish a common theoretical framework and vocabulary through which to accomplish the work. This was achieved in a variety of ways, including sharing and discussing readings, and making presentations to one another.

The team identified engaging stakeholders external to the core group as critical to the efforts because of the diversity of those stakeholders. Efforts to engage other faculty members and practitioners have included not only traditional publications but also presentations with an explicit invitation to the audience for feedback, workshops in which larger groups participate in project development and provide feedback, and follow-up to encourage adoption and seek additional suggestions for changes.

*Products*

Core personnel have identified short term and long term products toward which the group can work. To date, the NTCP has developed: learning outcomes for the introductory transportation engineering course, a set of knowledge tables that support the learning outcomes, and 60 ranking tasks that instructors can adopt to support a course designed around the learning outcomes and knowledge tables. Work-in-progress updates as these products have been developed have been valuable for engaging stakeholders and providing accountability. A repository (http://nationaltransportationcurriculumproject.wordpress.com/) collects all products to encourage awareness and adoption. The positive reception given these materials by attendees at the 2012 workshop and as documented through follow-up surveys demonstrates that external stakeholders are finding value in the work of the team.

**Conclusion**

The National Transportation Curriculum Project has produced materials that have the potential to improve transportation engineering education at a national scale. The NTCP's model could be adopted and adapted to improve education in any other engineering sub-discipline. Colleagues considering adopting and adapting the NTCP's model should consider the following:

- Number and diversity of core participants. The broader the sub-discipline, the larger the group might need to be. It is easier to build trust quickly in a smaller group, and it is easier to schedule meetings; these encourage continued participation.
- Regular virtual meetings build community and sustain project momentum. Email is useful, but it has not proven to be an effective substitute for voice and in-person meetings.
- Focus on key products. Having short-term deliverables creates a healthy sense of urgency and provides opportunities to engage stakeholders.

The NTCP continues its work in documenting and developing learning activities for the introductory transportation engineering course and in developing a better understanding of how transportation engineering faculty members interact in doing so. The proposed model for collaborative curriculum development can be adapted by colleagues in other civil engineering sub-disciplines to work across institutional boundaries and improve the education of civil engineers. Current work includes analysis of the results of the NSF-funded workshop and development and dissemination of the activities developed.

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