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Engagement of Practitioners to Produce Balanced and Fundamentally Well Grounded Civil Engineers

Dr. Isaac L. Howard PE, Mississippi State University

Isaac L. Howard is the Materials and Construction Industries Endowed Chair within the Civil and Environmental Engineering Department at Mississippi State University. He is a member of the Bagley College of Engineering's Academy of Distinguished Teachers and obtained bachelors, masters, and doctoral degrees in Civil Engineering from Arkansas State University, West Virginia University, and the University of Arkansas, respectively.

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Abstract

This paper describes a materials program within a department of Civil and Environmental Engineering designed to produce engineering graduates that are balanced and well grounded in fundamental concepts. Emphasis was placed on bachelors, masters, and doctoral students, as well as opportunities in and out of the classroom. Engagement of practitioners is a key component of the work. The primary objective of this paper is to present the university's materials engineering program, describe practitioner's roles therein, and present information on how and why practitioner involvement has been beneficial. A special topics course offering that allowed students access to a construction project is highlighted since it provides opportunities to describe how practitioners can assist with producing balanced and well grounded graduates. The primary assessment of this paper is the program as described seems to be working.

Introduction

Over the past few years, the materials area within the Civil and Environmental Engineering (CEE) department at Mississippi State University (MSU) has prioritized producing engineering graduates that are balanced and well grounded in fundamental concepts. To do so, emphasis has been given to development and sustainment of a sound program at bachelors, masters, and doctoral levels with instructional opportunities in and out of the classroom. Practitioner engagement (e.g. agencies, consultants, contractors, material suppliers, private laboratories) has been a key component of this process, and is the focus of this paper. Practitioner involvement is: 1) important to the educational process; 2) not always easy to obtain; 3) not always easy to effectively utilize; 4) a key to the presence or absence of balance; and 5) debated amongst education literature. Key items that resonate through this paper are the student opportunities created by balance, and how practitioners fit into this balance.

Industry and agency collaboration concepts are nothing new and are discussed in literature[1-5]. The amount or extent of these collaborations, however, is debated within education literature. Kavazanjian[5] indicated true collaboration between university professors and practicing engineers remains a rarity due to ignorance from both groups. Alahmad et al.[1] took a more collaborative viewpoint related to "living lab" concepts when describing professionals and professors teaching together and the resulting automatic integration of theory and practice.

The author presents information suggesting industry and academia interaction does exist at some universities. These interactions have value, but effort is required from both groups and the process isn't always easy (rarely are valuable activities easy). Cases where industry, academic professionals, students, and society benefit are win[4] situations[5]. These cases require integration of everyone toward one goal, which needs to be led by academia. This integration is helpful to achieve a win[4] situation, but it is also helpful in and of itself as it teaches a critical skill that, according to some is lacking[6]. A recent interview in a magazine of the American Society of Civil Engineers (ASCE) noted the diversity of the profession, while posing questions such as who integrates specialists together and who is looking at the big picture[6]. The answer that could be inferred is there is a need for these skills in the workplace.

Objectives and Scope

This paper's primary objectives are to present the MSU CEE materials program, describe practitioner's roles therein, and illustrate how and why practitioner involvement has been beneficial. Specifically: 1) that engaging practitioners can be helpful to maintain balance; 2) that practitioners can be helpful as an assessment tool relative to producing engineering graduates that are well grounded in fundamental concepts; and 3) that practitioner impact can be enhanced within a balanced program differently than in a program with unbalanced emphasis (e.g. bachelors students emphasized over doctoral students, or vice versa). The word balance as used in this paper can generally be taken to mean that the program does not prioritize one level of education (bachelors, masters, or doctoral) over another and that when balanced each level of education compliments the others.

To accomplish these objectives, the primary content of this paper has been divided into five sections. First, obstacles to achieving and maintaining a balanced program at MSU are presented, followed by a description of the materials program that is provided for contextual purposes. Next, practitioner feedback over a five year period from 2008 through 2012 is provided for MSU's materials program. The remaining two sections provide examples where fundamental concepts were implemented into courses with practitioner support in the 2013 to 2014 time frame that consider feedback obtained about activities from 2008 through 2012. This paper does not employ sophisticated educational research techniques, nor does it have large survey data sets. The majority of the assessment data utilized in this paper is from individuals associated with the author and/or the MSU CEE materials program, so bias possibilities should be noted.

Obstacles to a Balanced Program

This section describes five obstacles believed by the author to be formidable when developing or sustaining a balanced program focusing on fundamental concepts. Several additional obstacles that are more universal (e.g. funding, faculty support) were omitted.

Obstacle 1-Maintaining Critical Student Masses: Enough opportunities are needed to engage students in a variety of manners, so that needs can be met over time. If opportunities drop below a threshold level, effects compound. For example, funded research is needed so undergraduates have a reason to be on campus during the summer to take a class. The reverse perspective is that a relevant class is needed to make the research more appealing. Another example is there needs to be enough undergraduates interested in an area to support graduate student research (enough graduates are also needed to guide undergraduates). Any of these areas decreasing below a critical mass could, in turn, negatively impact other areas and upset the program's balance.

Obstacle 2-The "Real World": A concern for some students is what they are doing in college doesn't apply to the "real world". This idea is often supported by friends, family, and those with a job in the "real world". Supplementing classroom instruction with hands on research can be useful in demonstrating that what is learned in college can apply to the "real world". For example, if students perform laboratory experiments for a class and thereafter visit a commercial facility for research where the same experiments are being performed, these students often change their view on the usefulness and credibility of their education.

Obstacle 3-Finding Natural Matches: Obstacles 1 and 2 are more related to student opportunities and interest, whereas obstacles 3 through 5 shift emphasis to practitioners. An interested student pool with adequate balance of undergraduate and graduate students is a useful step toward gaining practitioner interest, especially if natural matches of common interest can be found. One example might be that a given industry has identified a problem but needs a large and unbiased data set to be publically available to raise awareness of the issue. Another example might be an agency has a large data set and needs a rigorous statistical analysis that requires software that is available on campus, but isn't available on a widespread basis within the agency.

Obstacle 4-Gaining Practitioner Confidence: Industry experts see a lack of cooperation between industry and engineering educators and they have brought criticisms and claims that higher education is not providing the engineers they need[2]. Cekic et al.[2] reported eleven practitioners indicated the main shortcomings of recent graduates are their lack of experiences and an absence of tangible examples from practice. Successfully overcoming obstacles 1 to 3 is helpful toward gaining confidence because practitioners see a balanced group of students ready to work on applied (and tangible) problems.

Obstacle 5-Optimizing Practitioner Input: Industry also seems willing to help develop engineering students[2]. This willingness, however, needs balanced and shaped into a form that is useful for the students. Faculty must be the bridge between all aspects of this process. A formidable challenge to optimal practitioner input can be likened to specifications on a highway construction project. Generally speaking, specifications can be method based (tell contractor how to place asphalt concrete), or end result based (tell contractor what properties are required for the asphalt concrete). Problems can, and sometimes do, arise when entities attempt to specify an end result (e.g. highway with a certain smoothness), but also want to cling to a few method based requirements (e.g. use a given profiler to help achieve smoothness). The author is of the perspective something similar to intermingling end result and method specifications happens in some cases with practitioners once they become motivated by alleviation of obstacles 1 to 4. They can tend to suggest lots of steps toward a desired end goal (i.e. balanced program well grounded in fundamental concepts), yet fail to recognize their most useful role is to help define needed fundamental concepts, then assist the faculty in helping to develop students with those skills. In almost every case, faculty will know their own students better than practitioners, and that knowledge can often be used for more optimal development. Faculty, however, need to be cautious not to fall into the reverse issue, as industry almost always knows their needs better than faculty. In the author's perspective, the best case scenario is for practitioners to be committed, then reply the equivalent of "we want X in the materials program, what is needed from us?".

Description of Materials Program

Over the seven year time period considered, the CEE materials program has been focused on applied teaching, research, and service activities with lesser theoretical emphasis. The program aims to provide opportunities in and out of the classroom and makes no distinction on where fundamental concepts are learned. The materials program as described in this paper begins in the second half of the junior year and goes through doctoral degrees. The program uses practitioner feedback (including feedback from recent graduates) as a guiding compass.

Table 1 summarizes materials course offerings, alongside student evaluations benchmarked relative to the CEE department, College of Engineering, and University. Student evaluations have been favorable for materials courses, offering some evidence the applied focus has been well received. Other information collected from students (e.g. exit interviews, surveys, impact statements) also suggest the applied focus has been well received with average responses on a 10 point scale being in the 9 to 10 range in most cases.

MSU's materials program is in some ways similar to the University of Arkansas (UA) approaches described a few years ago that were reported to be favorably received by practitioners[4]. Both align more closely to professional (as opposed to academic) models for laboratory activities. MSU uses professional specifications (e.g. ASTM, AASHTO, state DOT) as opposed to laboratory manuals. Also, writing assignments are more closely aligned to professional reports than to weekly reporting of findings, since most practitioners submit fewer, yet more comprehensive, reports to clients. In CE 3311, four reports are submitted for all laboratory exercises performed (one report for soil/ stabilization, aggregates, concrete, and asphalt) that also include content related to applications and mix designs.

Table 1. Relevant Courses Taught by Author from January 2008 Through December 2014

CE Course Code	Course Title	Level	Student Evaluations[B-D]
3311 or 3313[A]	Construction Materials Laboratory	Undergraduate-Junior	5, 4.1, 3.8 to 4.5
3313	Construction Materials Lecture	Undergraduate-Junior	6, 4.5, 4.3 to 4.7
4990	Special Topic: Pavement Performance	Undergraduate-Senior	1, 4.9
4103/6103	Pavement Materials & Design	Undergraduate-Senior & Graduate	6, 4.5, 4.2 to 4.7
4990/6990	Special Topic: Asphalt Durability	Undergraduate-Senior & Graduate	1, 5.0
7000	Directed Individual Study	Graduate	Not Evaluated
8303	Material Characterization	Graduate	2, 4.4, 4.2 to 4.5
8333	Pavement Rehabilitation	Graduate	1, 4.8
8343	Advanced Pavement Materials	Graduate	1, 4.7
8990	Special Topic: Warm Mixed Asphalt	Graduate	1, 5.0

A: Construction Materials Laboratory was a non-credit producing part of CE 3313 from 2008 through 2013, and became a 1 credit hour producing laboratory (CE 3311) in 2014.

B: All evaluations data is organized as follows: number of semesters evaluated, average evaluation, range of evaluations (ranges provided only if course evaluated more than one time). Evaluations are on 5 point scale.

C: Representative student evaluation questions are grouped together and listed below.

- The instructor: created high expectations, made the class interesting, conveyed content effectively, was enthuastic, was accessible, presented content in a manner suitable for learning.
- Students: did they learn a great deal, did they feel tests/assignments were fair and reflected class content and were graded in a reasonable time, would they recommend instructor to others, did they feel laboratory exercises were supervised properly for safety, and did they feel laboratory facilities were adequate.

D: There were fifteen semesters (fall and spring) evaluated to produce the information provided below (evaluations reported to nearest 0.1); spring 2007 through spring 2014 were used as fall 2014 data was not yet available.

- Civil & Environmental Engineering Department: Average = 4.0, Range = 3.7 to 4.2.
- College of Engineering: Average = 4.1, Range = 4.0 to 4.2.
- University: Average = 4.2, Range = 4.2 to 4.3.

Within the Table 1 courses, guest lectures by practitioners and plant tours are fairly routine. Critical thinking and writing skills are prioritized for undergraduates so that they reinforce fundamental concepts and calculations, as most engineering students are not comfortable with writing. Graduate students are required to utilize existing knowledge and skills to deliver products (e.g. written reports). Often, graduate student assignments are related to emerging topics (e.g. warm mixed asphalt) that lend themselves well to interaction with practitioners to complete the assignment. Courses are supplemented with service and research as follows.

Example service activities that occurred while the author was the ASCE student chapter faculty advisor where practitioners were involved are: 1) practitioner speakers for bi-weekly student meetings; and 2) panel discussions between students and practitioners regarding: a) what to expect during the first five years of employment, and b) civil infrastructure. Research has been used as an educational tool and as a primary means of developing continuity between the undergraduate and graduate programs while balancing the entire program. Over twenty students have completed masters or doctoral degrees, and tens of thousands of funded hours have been worked by undergraduate students on research during the seven year period of interest. One reason for this continuity and balance is believed to be pursuing several applied research projects where junior and senior level undergraduates can assist graduate students with activities such as material sampling, processing, batching, specimen preparation, testing, and data organization. Several of these funded projects have been related to civil infrastructure (e.g. airfields, bridges, highways, and levees) with large experimental components. The projects have often been related to more sustainable materials, improving material performance, and/or design/construction specifications, all of which are often of interest to practitioners such as agencies, contractors, and material suppliers. Balance begins to be achieved when students and practitioners are both motivated to participate in the projects, and once this occurs all groups benefit from the presence of each other. Also, the applied projects are very good at reinforcing fundamental concepts.

Undergraduates benefit from graduate student, practitioner, and faculty mentoring, while gaining hands on experience. Many of these undergraduates end up as graduate students in the same program, and/or end up employed at the same organizations as the practitioners involved in their activities. Graduate students benefit from the undergraduate support, but also benefit from the experience of organizing, managing, and teaching them. Graduate students also benefit from practitioner interaction in the same manner as undergraduates. Practitioners benefit by being involved in applied projects that can end up being implemented in their markets, and by being able to more effectively recruit more experienced students employees. Conducting research of interest to industry and agencies helps to maintain practitioner relationships[3] and balance. The university (and faculty) benefit from a more efficient system that helps them simultaneously accomplish their core missions of education, research, and service.

Laboratory facilities and equipment are essential to achieve balance through applied activities as described in the previous paragraph. Everyone mentioned in the previous paragraphs benefits from well-equipped and spacious laboratory facilities; research (or other external support) is a key to such facilities. Laboratory and hands on experiences come at a cost[7]. Benefits from suitable laboratories actually go beyond use of the facilities, as students begin to understand and appreciate the difficulty of properly maintaining laboratories. When, for example, students: 1) participate in the external calibration process, 2) use calibration curves, 3) are involved in regular safety meetings, and 4) observe hazardous waste management (or in some cases are certified and involved in the process), these can be good educational tools.

Practitioner Feedback - 2008 Through 2012 Calendar Years

The author has relied upon practitioners for guidance and support related to all aspects of the MSU-CEE materials program to date. Similar reliance on practitioners can be found in literature (e.g.[3]). The practitioner feedback provided in this section was originally collected for purposes outside this paper by an MSU staff member. The only stipulations communicated to practitioners were to focus on the 2008 through 2012 time period and limit their feedback to the author of this paper. They understood that descriptions or evidence of student learning were of interest. Table 2 summarizes the numerical feedback obtained. In addition, practitioners were invited to provide brief impact statements. Eight impact statements were provided, and two are shown below as examples; one statement focuses on undergraduate students and the other on graduate students. One of these statements was from a paving company executive, and the other an emeritus employee of a national agency and asphalt research center director.

Table 2. Survey of Industry and Agency Construction Materials Groups

Question	n	Avg.	Range
Do you feel students are provided useable and fundamental skills applicable to construction materials?	8	9.5	9 to 10
Are you supportive of the way classroom instruction is supplemented with hands on undergraduate research?	8	9.5	8 to 10
Is industry appropriately used within classroom instruction to further students understanding of construction materials?	8	9.4	8 to 10

--1 = very poor (or strongly disagree) and 10 = excellent (or strongly agree)
-- n = number of responses, Avg. = average of responses, Range = range of responses

"I've worked with Dr. Howard on several construction materials research projects over the past four years and have closely witnessed, first hand, his interaction with grad students and industry professionals. His understanding of business economics - and how it relates to the engineering of construction materials - is exceptional; along with his ability to strongly convey that to his students. His teaching principles of effort, efficiency, education and experience - with accuracy and integrity - will well equip his students for workplace leadership in agency and industry fields."

"Dr. Howard does an excellent job of supplementing classroom instruction with hands-on laboratory work for undergraduate students. Because of this effort many of these students are encouraged to pursue a graduate degree related to construction materials. All of his students upon graduation have an excellent appreciation of laboratory testing as it relates to research, mix design, and control of materials during construction."

Description of Special Topic Course Related to Asphalt Durability - Summer 2013

The course presented in this section considered the previous section's feedback and is referred to as AD hereafter, which is *CE 4990/6990-Special Topic: Asphalt Durability* (Table 1). Only the

AD course details that pertain to practitioners, fundamental concepts, and balance are provided. The AD course also paralled efforts by other educators in some areas; four such examples are provided at the end of this section.

The AD course familiarized students with material properties that affect durability of asphalt pavements, and an airfield was used as the basis since durability is needed around aircraft. Reconstruction of a runway at the Columbus Air Force Base (CAFB) was the focal point, which coincided with CAFB work performed by a since graduated doctoral student who was not enrolled in the course[8]. This is an example synergy brought upon by a balanced program. Since students were on campus working on other projects, this enabled sufficient enrollment for an applied course. Also, the work of James[8], which dealt with eleven airfields, facilitated the CAFB avenue, as did practitioner relationships already in place. The since graduated doctoral student also guided and/or participated in some activities, and was another resource for enrolled students.

Key elements of the course were: ten fundamental learning outcomes, graduate student leadership tasks, and a final presentation to twelve practitioners. Students with different experience levels were challenged in this project in different ways and ultimately complimented each other. Overall, students saw the major facets of the air force base construction; i.e., 'cradle to grave'. A recurring theme iterated to the students was: "strive to do work of such quality that you would want someone to see it, not that you would be afraid that someone might see it." This theme was credible to students because of practitioner involvement.

The learning outcomes are summarized below, and example photos of students completing these outcomes are shown in Figure 1. Ability to perform these outcomes was required for all seven enrolled students: four undergraduates, two first-semester masters students, and one doctoral student (note that the enrolled students were among the best of the MSU materials program). This ability could be developed through this course or already be possessed by the student (e.g. doctoral student had proficiency in many of these outcomes at the beginning of the course).

1. Read background information on asphalt durability.
2. Develop a test plan.
3. Determine needed raw materials and obtain samples from paving facility.
4. Organize materials by developing a labeling and tracking system.
5. Determine and execute a materials processing plan.
6. Develop batch sheet for use in conjunction with the material processing plan developed.
7. Perform asphalt mix design and corresponding volumetric calculations for CAFB.
8. Develop alternative mix designs based on CAFB to understand durability implications.
9. Test mix designs for durability related properties (e.g. Cantabro mass loss).
10. Observe asphalt production, asphalt placement, and sample/test plant mixed asphalt.

In addition to the outcomes, each graduate student was given an additional durability task. One masters student was tasked with reviewing allowable gradations of several agencies, and the other was tasked with data analysis. The doctoral student was given a cracking investigation (a more complicated task that in retrospect may not have been optimal). Graduate students were to incorporate undergraduates into their tasks as a function of undergraduate interest, primarily for gaining some management and leadership experiences for the graduate students. The masters students were to look to the doctoral student for guidance on their tasks as needed.

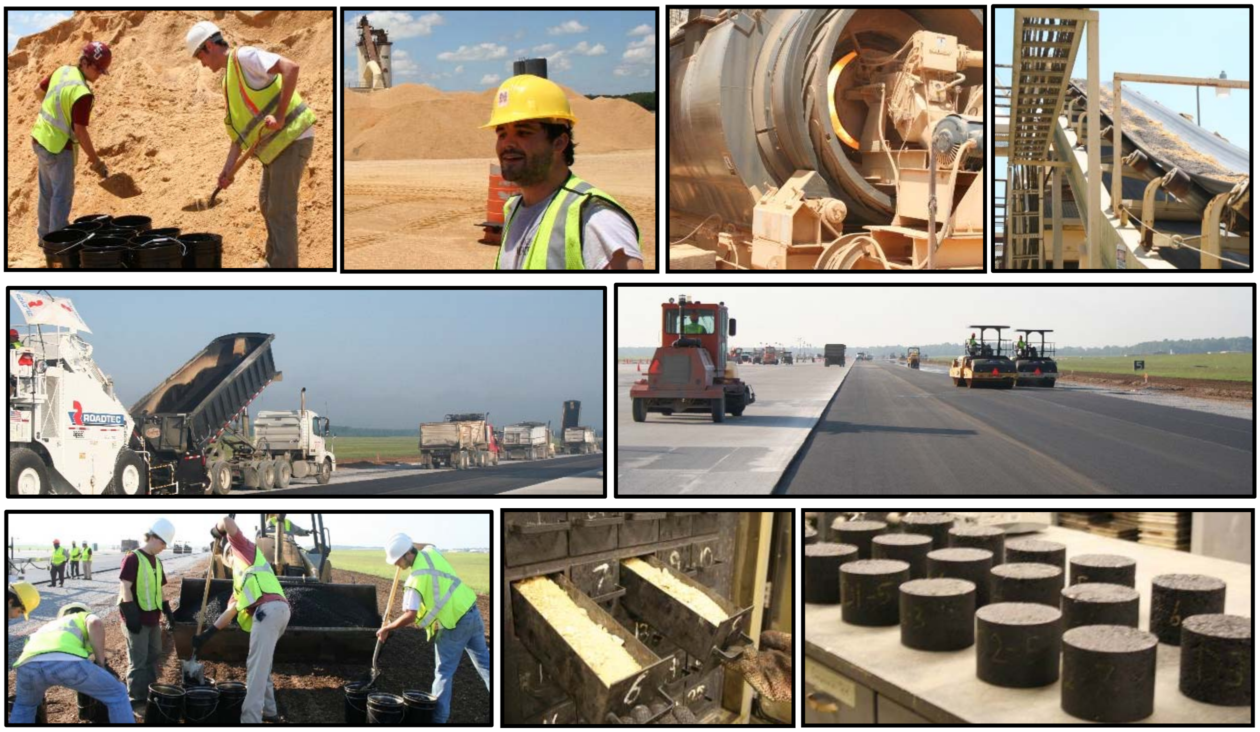

Figure 1. Example Photos Showing Students Field and Laboratory Experiences

Students were given suggested hourly estimates for the course for planning, and also to emphasize that practitioners often document their work for billing, but they were also told that their grade was not a function of hours worked. Hourly estimates were based on the conventionally recommended 2 hr. out of class per hour in class (undergraduate suggested effort was around 135 hr., and graduate suggested effort was around 150 hr.). These estimates were couched by stating that working 30 or 300 hours was equally bad. Graduate students reported 144 to 151 hours, and undergraduates reported 123 to 138 hours. Students reported their hours according to categories of their choosing. Discussions occurred throughout the course on where their time was going versus where they thought it would go to show some practical items are more time consuming than they appear.

Final presentations began with a course overview from the instructor. Next, two practitioners discussed: 1) national groups that work with asphalt paving (e.g. National Asphalt Pavement Association); 2) the importance of each entity (e.g. agencies, consultants, contractors) to quality paving. Next, student presentations occurred for around two hours (Figure 2 is an example), with informal time to interact with students on either side of these presentations. Graduate students who presented (doctoral student did not present, rather helped others develop their presentations) each presented graduate tasks. Masters students began and ended the presentation as these portions can be more difficult. Undergraduates each presented a few of the ten outcomes.

Practitioners were given a survey and could either identify themselves or be anonymous. Eleven of the twelve attendees filled out the survey (Table 3). Of the twelve attendees, there were: three from the Mississippi Department of Transportation (MDOT); three from a private consulting firm; one paving contractor; one retired from the US Army Corps of Engineers (USACE); two from a testing laboratory; two from a material supply company. Survey results were positive and consistent with the feedback presented over the 2008 to 2012 calendar year (note that in a few cases, those responding to the Table 2 survey and the Table 3 survey were the same).

Figure 2. Example Photographs of Final Student Presentations to Practitioners

In the author's assessment, students were able to transition their perspective relative to practitioners from anxiety to anxiousness to confidence to accomplishment to acceptance through this course. The overall experience was successful. The main shortcoming was interaction of undergraduates with the doctoral student on the cracking task. More should probably have been done by the instructor as this activity had some interaction, but not as much as the other graduate tasks. The doctoral student fully interacted with the others on fundamental tasks and presentation development, but less so on the cracking task. Undergraduates were given considerable freedom with respect to which graduate student tasks they interacted with.

Table 3. Results of Practitioners Survey of AD Course

Question	n	Avg.	Range
1. Did the students demonstrate fundamental understanding of asphalt materials and paving practices? *Non-numerical responses (3): a) Absolutely, Very nice job; b) Yes-Great Job!; c) Yes, very good*	8	9.5	8 to 10
2. Did the students demonstrate an understanding of asphalt durability? *Non-numerical responses (3): a) Yes; b) Yes; c) Yes*	8	9.5	8 to 10
3. This course was intended to familiarize students with material properties that affect asphalt durability, but also to provide multiple hands on fundamental type experiences. Based on your assessment of the final class presentation, did it? *Non-numerical responses (3): a) Yes; b) Yes; c) Yes*	8	9.6	8 to 10
4. In your assessment, do classes of this nature help prepare students for careers in asphalt paving? *Non-numerical responses (3): a) Absolutely; b) Very Much!; c) Yes, very good*	8	9.8	8 to 10
5. In your assessment, was industry/agency support used effectively during the project and as a panel for the final presentation? *Non-numerical responses (4): a) Yes; b) Yes; c) Yes; d) ---*	6	10.0	10 to 10
6. Additional comments were requested, which are provided below (some provided more than one comment, while others provided no additional comments). *Non-numerical responses (11): a) It was unclear if all students were involved in all steps; b) Students understood questions and answered them well; c) This is a very good partnership; d) Very good to see that time and money was involved besides just book info; e) Love the concept; f) Excellent job by your students, thanks for including me!; g) Excellent !!! Thanks; h) Very good presentation. Thanks!!; i) Very good class; impressed; j) Great presentations and communication skills; k) It seemed that all involved did a good job.*	---	---	---

--1 = very poor (or strongly disagree) and 10 = excellent (or strongly agree)
-- n = number of numerical responses, Avg. = average of responses, Range = range of responses

AD was intended to provide a 'cradle to grave' experience. Hall[4] describes 'cradle to grave' concepts for construction materials beginning with material sampling and ending with design report preparation. The AD course also incorporated concepts from[7]. Specifically, the idea that students learn best when they are actively seeking needed information, and that they use higher-order thinking to accomplish their tasks when the teacher is the "guide on the side" as opposed to the "sage on the stage".

Dennis[9] describes use of students with work experience as team leaders to promote peer-to-peer teaching and learning within a senior level engineering course. Pairings grouped experienced (i.e. those with work experience) students with non-experienced students. These pairings were for a multi-component semester long scenario based design experiment. Pairing graduate students with senior level undergraduates within the AD course was intended to promote peer-to-peer teaching and learning. In addition, the AD course provided something for visual, auditory, active, and sequential learning styles, similar to the "living lab" described by[1]. The AD course and the "living lab" also provided perspectives on size and scale and afforded students access to initial designs (e.g. construction plans, mix designs) and access to the actual product.

Continuing Practitioner Involvement - Summer 2014

The summer following the AD course, practitioners were again involved with fundamental skill development. Two students enrolled in *CE 7000-Directed Individual Study* (Table 1) focusing on asphalt binders gave a final presentation of their work to fourteen industry and agency practitioners. Similar to the AD course, students were aware of industry participation, in particular, their final presentation. A key difference relative to the AD course was that most of the activities occurred at a testing and development laboratory where the students were trained by their personnel and thereafter conducted experiments that were subsequently used for their analysis and final presentations.

Summary and Conclusions

Incorporation of practitioners into a balanced program focused on fundamental concepts seems to be working at MSU, and also seems to motivate students. The author is of the perspective that a balanced program provides better opportunities to effectively incorporate practitioners (especially when they are viewed as part of the balance), though the process has obstacles. The concepts presented herein should be applicable to any construction material or industry.

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