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Towards Broader Adoption of Educational Innovations in Undergraduate Water Resources Engineering: Views from Academia and Industry

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Abstract: This article investigates the challenges that face the development, community-scale adoption, and long-term sustainability of educational innovations in the field of hydrology and water resources engineering undergraduate education. Adopting a customer-based discovery process, the current study conducted a set of 78 informal interviews with two main groups: faculty members who teach water resources and hydrology courses, and practicing engineers with specialty in the same field. The interviews revealed that the main motivation for faculty to develop or adopt new educational innovations stems from self-efficacy and desire to achieve effective instructional strategies. Other factors, such as institutional requirements and faculty evaluations and incentives, seem to play a modulating role for generating self-created motivation. The results identified time limitations and steep learning-curves as the two adoption hindering factors cited by a majority of the interviewees. Other hindering factors reported were rigidity of resources and lack of assessment data. Industry perspectives on preparedness of recent graduates and relation to current educational practices showed that young engineers may lack critical skills on the proper use and interpretation of data and modeling analyses. The study also discusses potential solutions, such as development of sharing environments to facilitate exchange of data and resources, modular design to support adaptation and compatibility with existing curricula, collaborative efforts to produce shareable evaluation and assessment data, and potential opportunities for collaboration between academia and the professional industry to facilitate development and sustainability of educational innovations.

Keywords: *water resources, education, innovations, adoption, interviews, academia, industry.*

Recent reviews of the literature emphasize the need for formalized approaches to reform hydrology and water resources engineering education (McIntosh and Taylor 2013; Seibert et al. 2013; Ruddell and Wagener 2014). These desired reforms call for tapping into discipline-based advances in data, modeling, and information systems; exposure to modern tools used in engineering practices; adoption of sound educational strategies such as active-learning; and use of real-world case studies to deliver authentic learning experiences. Examples of recent educational developments that strive to introduce pedagogical changes in hydrology and water resources engineering education include development of web-based learning modules (Habib et al. 2012a; Yigzaw et al. 2013; Habib et al. 2018), computer models,and simulation games (Hoekstra 2012; Merwade and Ruddel 2012; Rusca et al. 2012; Seibert and Vis 2012; AghaKouchak et al. 2013; Sanchez et al. 2016), sharing of educational materials via community platforms (Wagener et al. 2012), use of hydrology real-world case studies (Wagener and Zappe 2008), use of geospatial and visualization technologies (Habib et al. 2012b), and the use of real-time environmental monitoring to enhance student engagement (McDonald et al. 2015; Brogan et al. 2016). However, these efforts face challenges in achieving scalability, sustainability, and community-scale adoption (Ruddell and Wagener 2014). This recurring problem has been a major concern for the institutional and financial investments by the STEM education community (McKenna et al. 2011; Singer et al. 2012). Barriers to scalability and adoption have been attributed to various issues such as characteristics of the innovation, faculty perceptions, student resistance, and institutional cultures and resources (Hardgrave et al. 2003; Rogers 2003; Heywood 2006). Rogers's (2003) theory on diffusion of innovation, considered one of the most relevant theoretical perspectives that can guide engineering education innovations (Borrego et al. 2010), identifies five innovation characteristics that influence adoption: relative advantage, compatibility, complexity, trialability, and observability. The ease of implementation and ease of use were also cited by Compeau et al. (2007) and Bourrie et al. (2014) as important factors. A survey of U.S. engineering departments (Borrego et al. 2010) identified several faculty issues that affect adoption of engineering education innovations, including faculty time for preparation and management of labor-intensive innovations, faculty resistance to change, and skepticism regarding evidence of improved student learning. While these factors apply across the general field of engineering education, there is a need to identify discipline-specific factors that may hinder or facilitate adoption of innovations. As suggested by Borrego et al. (2016), the value of a certain innovation varies according to the specific engineering discipline, simply due to the specific technical skills and educational content pertaining to the discipline. This is also supported by earlier studies on behavioral prediction and behavior change (e.g., Theory of Planned Behavior, Ajzen 2018) that link an individual's behavioral intentions and actual behaviors to subjective norms and perceived behavioral control. The likelihood of adoption increases among peers of the same discipline as they share their own developments and communicate experiences in using and deploying the new innovations. Therefore, research on innovation adoption and diffusion has been recommended at the discipline and sub-discipline scales as a strategy for understanding the effectiveness of engineering and science education initiatives and their adoption potential (Henderson et al. 2012; Finelli et al. 2014; Khatri et al. 2016). Examples of pioneering efforts focused on specific engineering disciplines are found in the fields of chemical engineering (e.g., Prince et al. 2013) and electrical and computer engineering (Froyd et al. 2013; Shekhar and Borrego 2016). Other studies offered cross-field comparative assessments (e.g., Cutler et al. 2012). Each engineering discipline has its own social system that controls the culture of adopting new educational innovations (Lattuca and Stark 1995; Wankat et al. 2002), and hydrology and water resources engineering is not an exception in this regard.

The current study reports results collected from a set of 78 informal, open-response qualitative interviews with hydrology and water resources faculty and engineering professionals. The study provides a customer-driven perspective on the propagation, scaling, and adoption of education innovations in the field of hydrology and water resources engineering. The term customer (or user as we refer to it later in the article) refers to the typical user of educational developments (e.g., faculty members teaching hydrology). The results provide insights on the needs, motivations, and hindering factors that affect engineering faculty as developers and potential adopters of educational innovations in this field. Such insights can be used to inform ongoing and future development and management of water resources engineering education innovations and avoid the undesirable paths of lack of adoption and long-term sustainability.

Methodology

Customer-Discovery Approach

The interviews discussed in this study were conducted by the authors as part of their participation in a customer-discovery program known as the Innovation Corps for Learning (I-Corps L) (Chavela Guerra et al. 2014; Smith et al. 2016). The I-Corps L program uses an entrepreneurial approach for business model generation and validation that was proposed earlier in the lean startup movement (e.g., Osterwalder and Pigneur 2010; Blank and Dorf 2012) and social entrepreneurship (e.g., Janus 2018). The main rationale behind this approach is that before expending a significant amount of resources on an innovation, the developer should first confirm that it addresses a specific problem or need of potential customers (or users, in the more general sense). The only way to test the viability of the innovation prior to investing exorbitant amounts of time and money is to get out of the building and talk to potential customers, identify their needs and existing problems, and how they currently manage such problems. Once the needs of users are identified and verified, the next steps in the I-Corps L process (not covered in this paper) focus on formulating a value proposition and looking for a business model on how to further pursue the proposed innovations, including market size and cost and revenue structures.

Adopting this approach, the authors conducted a total of 100 interviews with potential users of educational developments in the area of hydrology and water resources engineering. The study reports on only 78 interviews that were conducted with members from academia and industry. The 22 remaining interviews were deemed uninformative (e.g., interviewees did not teach undergraduate courses, did not teach relevant courses, or did not provide relevant inputs) and as such were excluded from our analysis. The interviews were designed with a customer-centered approach (i.e., focusing on what a user needs from an educational innovation), rather than a developer-centered mindset (i.e., focusing on a specific product or innovation). Using an informal, open-ended interview design (Patton 1990), the interview questions were fairly short and not overly specific, allowing the interviewee to be the center of the conversation. Interviews were conducted either in person, over the phone, or via a teleconferencing venue, and ranged from 30 to 60 minutes. The range of people interviewed in the current study was quite broad in order to capture the hydrology education landscape from as many different points of view as possible. Generally, the interviews were divided into two main categories: academia and industry. The following are brief summaries of each category, including distinction of user segments within each group and what was asked during the interviews.

Interviews with Academia

Academia, in the context of this paper, refers to interviewees associated with post-secondary hydrology and water resources education in civil engineering and geoscience programs. A total of 42 interviews were conducted with instructors from different types of educational institutions including research- and instructional-intensive, and small and large four-year universities. The majority of interviewees were from institutions with medium to intensive research focus, while just eight were from instructional-focused institutions. Three-quarters of the institutions were mid to large-size programs, with the remaining one-quarter considered small in size. These institutions were spread across the United States, covering 22 states, and included faculty with different specializations within the overall domain of water resources and hydrology. The interviewees were about two thirds from civil engineering departments and the rest were from earth sciences. The authors recognize the differences between hydrology as an earth-science, and water resources engineering as an applied field, and the implications of such differences from an educational perspective. However, due to the significant overlap between the two fields and how they are actually taught in both engineering and science departments, a decision was made to not explicitly differentiate between them in designing the interviews and in selecting the potential faculty interviewees.

The main interview questions with academia are summarized as follows:

i. What type of pedagogies are currently being used in the classroom? Is there a need to reform the undergraduate hydrology and water resources curriculum?
ii. Do instructors currently use emerging technologies in the undergraduate classroom? If so, in what way, and if not, why not?
iii. Do instructors look for innovative educational material to use in their classroom? If so, where do they look?
iv. What are the issues with teaching engineering-industry tools and techniques in the classroom? What are the challenges of developing material that encompasses these tools?
v. What is the incentive for instructors to improve their teaching methods using innovative contents and new resources?

Interviews with Industry

Industry needs skilled graduates who are capable of applying hydrologic concepts taught in the classroom to practical real-world engineering problems (DiNatale 2008; Eisel 2008). In today's technology-driven society, and with the recent advancements in data and hydro-informatics, this often requires a deep knowledge of a number of computer applications, data processing tools, and simulation models. Thus, interviewing engineering professionals from industry was important for two main reasons. The first was for an assessment of the preparedness of graduating students to perform on the job, and how this can be traced back to strengths and weaknesses from an undergraduate education perspective. Secondly, it was of interest to discover what type of post-graduation training professionals find necessary, how it is provided, and whether opportunities exist for academia-industry collaborations in addressing undergraduate educational reforms. A total of 36 interviews were conducted with practicing engineers. To capture the full spectrum of industry, both private (consulting firms) and public sectors (state and federal water resources agencies) were considered, along with a good mix in the size (small, medium, and large) of organizations. The breakdown of the interviewees included a mix of junior engineers and senior engineers or managers, with somewhat more from the latter group. The junior engineers were fresh out of school and could provide insight into the transition from an undergraduate setting to the workplace from a first-person point of view. Senior engineers provided a third-person perspective on the transition of recent graduates to the workplace, giving insight on the evolution of the young engineers. The managerial perspective, of course, provides logistical information associated with the training and professional development of engineers.

The main interview questions for industry professionals are summarized as follows:

i. What is the level of preparedness of graduating water resources engineers as they enter their first job and progress in their career?
ii. Are there any certain gaps in basic knowledge and applied skills that should be addressed at the undergraduate level?
iii. What are the current post-graduation training and professional development strategies?
iv. Are there any opportunities for universities to use advances from the professional field and enhance undergraduate education?

Results: Views from Academia

A total of 42 interviews were conducted with university professors teaching water resources and hydrology related courses. During these interviews, the authors first tried to decipher the motivation underlying the desire to enhance the undergraduate hydrology and water resources engineering education, then discussed challenges associated with developing, discovering, and utilizing innovative resources and materials.

Motivators: What motivates instructors to incorporate innovative teaching materials?

The faculty interviewees expressed a need for improving education in the fields of hydrology and water resources engineering. The majority of the interviews indicated that the main source of motivation to improve course content and teaching strategies is self-created and derives from one's desire to excel at endeavors associated with his or her career. Achievement, self-esteem, and self-efficacy play a large role in this. However, based on interviewees' statements, this source of motivation is modulated and affected by institutional and faculty factors. The interviewees indicated that incentives such as program accreditation, performance reviews, and pressure from superiors (deans/department heads) are not the predominant factors. Instead, factors related to instructor's experience (i.e., junior or experienced) and instructor's priorities (i.e., research or teaching) were highlighted by some of the interviewees to possibly influence the tendency to participate in innovative instructional strategies.

Junior instructors tend to be very ambitious and are likely to strive to bring something new to their classrooms. Additionally, they are more accustomed to quickly adjusting their ways to take advantage of new advancements. Often, they are in the process of developing their courses and want to do so in a way that is most effective and well informed by recent educational research. In contrast, the experienced instructors who have been teaching for many years already have a working curriculum that has been developed, utilized, and proven. This reluctance to change is logical and well-understood, and is often hard to argue with, especially given the lack of tangible incentives. The argument is, however, that the teacher-centered techniques favored by experienced instructors have been proven substantially less efficient in transferring knowledge compared to more contemporary student-centered approaches (e.g., Prince 2004; Cornelius-White 2007; Wright and Weimer 2011).

The variability in priorities amongst universities can also play a major role in course content and methods used in presenting such content. These priorities are often apparent at the level of the individual professor within a university, i.e., emphasis on instruction or research. Professors with high emphasis on teaching tend to adopt new pedagogies and expand the content of their courses more readily than those with more research-focused obligations. From the perspective of the researchers, why invest time and effort into improving a course when the time could better be spent on research, which will have the benefit of improving their professional standing and career advancement. The inverse here, of course, applies to those with high teaching emphasis.

Hindering Factors: What Hinders Developing and Utilizing Innovative Educational Resources?

Interviews with academia members showed that there are many challenges when it comes to sustainable development and utilization of innovative materials. These issues have been summarized into five categories: time limitations, steep learning curves, refurbishing requirements, rigidity of material, and lack of assessment data. Out of these five categories, the first two were cited by nearly all of the interviewees. The importance and relevance of each of these challenges are discussed in the following sections. It should be noted that these challenges are not additive, rather they are highly interactive; i.e., a solution to one may provide a means for overcoming another or, conversely, have an adverse effect on the other.

Time Limitations. Time requirement was by far the most cited hindering factor by nearly all of the interviewees. While instructors see the need for restructuring of the current curriculum, they are either too busy or are not knowledgeable enough to develop new material that addresses emerging resources such as modeling and data analysis techniques. As one of the interviewees stated: "In undergraduate courses, I introduce some modeling software, but only at the level of presentation with no actual use, mainly due to lack of time, but could also be due to lack of material that is ready to use especially in areas out of my immediate specialty." Developing innovative resources is difficult because it requires knowledge in both the subject matter and on educational research. Finding effective pedagogies (e.g., active-learning strategies, problem-based learning) and then structuring material in a way that is presentable to students can be challenging and time-consuming. Most interviewees indicated that they look for peer-developed material. While this solves the pain of developing one's own material, many of the other pains persist and some are magnified. For instance, using peer-developed material that utilizes an unfamiliar software, project, or dataset, may present a learning curve for the professor who is implementing it. Aside from development time, there is also a time requirement for preparation and implementation. One instructor stated that "dynamic lecture material (e.g., case studies with continuously changing datasets) takes too much time and effort to prepare and maintain." It was also the opinion of many interviewees that new, innovative resources should not replace existing material; rather, they should augment it, simply due to the mostly supplementary nature of these new resources. It is easy to see how this translates to more lesson preparation time, strain on class time with an already over-loaded curriculum, more out-of-class time with students (e.g., office hours, email communication), and evaluation and assessment time.

Steep Learning Curves. This was another factor that was cited by a majority of the interviewees who expressed that a large issue for them is the steep learning curve involved when using new, unfamiliar tools and techniques that are part of an innovative resource. For example, one of the interviewees stated that "Pre-customized case studies are useful but professors have to get familiar with these specific cases, which could be a burden to learn and spend time before they assign it to students." Interviewees also indicated that incorporating these advancements in the classroom is problematic for students as well, due to the difficulty in learning to use new tools or software, which might generate student resistance to the new resources. Students must be trained to use a computational model, a GIS tool, or other software before they can apply it in a useful way. This issue was clearly stated by one of the interviewees: "Solution is to build guidance and support mechanisms to students to reduce the learning curve – no matter which different material we choose to use, we need to make sure that we reduce the learning curve for students." The interplay between students' resistance to new materials and faculty's decisions to adopt these materials was also iterated by one of the interviewees: "Adopting digital resources for learning is much needed by the community, but this depends on the level of students and how they are prepared to engage in modelling and data-based analysis; so could be appreciated by the professor, but the challenge is the level of students." Effectively using computational tools and models is not straightforward and is considered an art by the community because of the experience required to use the tool appropriately. Many of these tools are rather crude and are far from intuitive, and even those with friendly graphical user interfaces are still ages behind the easy-to-use mainstream software that students are accustomed to (e.g., online maps, spreadsheet and word processing software). While huge strides have been made in making such tools more user friendly, models need to be properly introduced to students to better understand their applicability and limitations and avoid serious misuse or faulty interpretation of results. The interviews also indicated that the steep learning curves are not only associated with software use, but also with the use of case-studies and real-world projects situated in specific regional basins that may not be familiar to the instructors. One instructor stated that: "I use a textbook that has lots of data applications, but these are mostly based in one state, which could be an obstacle." Despite their educational value, region-specific case studies often require the instructors to learn about the particular basin and the hydrologic problems that pertain to that basin, which might render these peer-authored resources less practical to adopt. This perhaps suggests that effective peer-authored resources should provide adequate context and user-support in order for them to be used effectively and to alleviate the learning curve of interested adopters.

Updating and Refurbishing. Another issue cited by the interviewers deals with the rate at which data and modeling tools become obsolete (e.g., data web links, software versions). Frustration with the high turnover of new materials can be a deterring factor for adoption since "technology glitches can take up class time" as stated by one of the interviewees. Changes to website interfaces and online data portals of major agencies that provide water resources datasets can cause rapid turnover of educational developments. To sustain this pace, data and modeling-based educational resources must be updated frequently in course material, which requires time and effort from the instructors. Compared to textbooks which receive updates (often just moderately modified forms of the previous versions) only every three to five years, materials that are dependent on dynamic resources require continuous adaptation. Additionally, updating of the materials is needed after feedback is received from students or other users. These usually take the form of assessment data on students' experiences with using the materials, impact on students' learning, and expansion or inclusion of supporting resources and improvement to the design of the new resource. Therefore, the ability to easily and quickly update materials is a critical feature that must be available to effectively sustain and scale new educational materials that emphasize the use of technology and research advancements.

Lack of Modularity and Customizability. The interview responses indicated that most instructors, especially those who are senior or those who are not able to commit significant instructional time, have well-developed courses and are simply looking for material that reinforces or supports their current curriculum. For their purpose, the interviewees indicated that resources should be very modular. As one interviewee said, "I need resources that are not 'too rigid', that are 'loose' in format and content; I am looking for 'a la carte' items, and not the 'whole menu'." In contrast, most of the interviewees from the early-career segment expressed an interest in material to build their class around and therefore were looking for larger, more holistic resources that can still be customized to their specific needs (e.g., different datasets or hydrologic basins).

The interviews revealed that material that is not tailored to the specific need of the implementing professor (in content or format) presents additional challenges for development and adoption. For example, will the material be presented during the lecture portion of the class, during laboratory time, as a homework assignment, or as a class project? Each option has its own benefits and challenges; for instance, including new material in the class or in the lab may prove difficult given time constraints and pre-existing course material. However, it may allow the instructor to directly interact with students and to readily provide expert guidance. This, of course, is made more difficult if assigned as an out-of-class assignment. In such cases, it is important for the developer to provide additional user support, specific to the needs of the local students to supplement the absence of the instructor (e.g., detailed instructions, screenshots, videos, templates). Conversely, providing too much support can result in adverse learning effects, where students follow steps blindly and without thinking about what they are trying to accomplish. The ability to modify (add or subtract) material easily is a desirable trait that was expressed by a considerable proportion of the sampled population of interviewees. This can allow instructors to use only a subsection of an existing resource and easily apply it to their needs e.g., changing the region of a case study, removing a section that is outside of the scope of the current class, or adding or removing user support.

Lack of Assessment Data and Tools. The need for both assessment tools (e.g., grading rubrics), as well as evaluation data on the potential value of the new material from a student learning perspective, were cited by some of the interviewees. Instructors often look for evidence (e.g., documented evaluation results on student performance) that the material is effective before implementing it in their class. This becomes a bit of a conundrum especially for pilot efforts which have yet to be tested. Typically, developers attain initial assessment data from their own institution; however, this is usually a rather limited sample size and results of the developer-implementation generally contain some level of bias. Furthermore, the interviewees highlighted another aspect related to the difficulty associated with grading students' work, especially when non-traditional material is being introduced, such as data and modeling techniques. As one of the interviewees stated, "I think the software itself can be useful but as it currently stands, if a student does the exercise, I have no easy way to grade the student."

Results: Views from Industry

A total of 36 practicing engineers were interviewed. Below is a summary of the results of these interviews with recurring topics of discussion on the level of preparedness of recent graduates and how post-graduation training relates to and builds on education at the undergraduate level.

Preparedness of Recent Graduates

Nearly all of the sampled population of senior engineers and managers indicated that young engineers specializing in hydrology and water resources must be able to utilize, understand, and develop models; interpret and analyze results; effectively identify and communicate key findings; and, more importantly, have fundamental knowledge on the theory underlying the model. Understanding when and where assumptions and approximations should be made, and being able to identify sources of uncertainties and articulate limitations of a modeling analysis, are important skills for young engineers, but are not consistently attained by new graduates, as many of the senior interviewees suggested. General knowledge of numerical modeling concepts was cited as a more desirable attribute than detailed training in a specific software. Priority was given to the former due to the large variation of tools and models used among consulting firms. In addition to modeling and data analysis skills, the majority of industry professionals stated that recent graduates typically have underdeveloped engineering soft skills, such as communication, creativity, adaptability, and collaboration. This was also iterated in interviews with engineers from government agencies. While the interviewees acknowledged that such skills are usually hard to teach in traditional classrooms, they expressed that the use of case-based, data and modeling-driven student projects, developed through collaboration with industry, present some unique opportunities to introduce these types of skills into the undergraduate curriculum.

Most of the young engineers who were interviewed were very eager to share their perspectives of undergraduate curriculum. While most of them felt that their undergraduate degree adequately prepared them for their first job, they stated that their knowledge of the use of computer models and related tools was lacking. They were quick to clarify, however, that it was not lack of conceptual or fundamental knowledge, but simply the lack of applicability within real-world hydrologic problems. Building on this, the interviewees complained that textbook problems often focus on using idealized and fairly narrow examples and lack the overall context of how hydrologic analysis can be pursued using data analytics and modeling approaches. This resonates with the comments presented earlier from the senior engineers on the skills needed by young engineers to be able to interpret results in the scope of the project at hand, as opposed to simply performing the analysis.

Post-graduation Training and Professional Development

Developing the skills associated with discipline-specific tools and techniques, engineering soft skills, and the ability to formulate solutions based upon contextual information, is a long-term process that does not end at the undergraduate level, but progresses slowly over several years of post-graduation training. Interviews with industry members were also intended to identify attributes of on-the-job training practices that might be leveraged and built upon in teaching these skills at the undergraduate level. Interviews with senior engineers and training managers indicated that training is obtained in the majority of consulting firms through informal techniques that utilize a mentor/apprentice approach, whereby a junior engineer works closely under a senior engineer until skills have been sufficiently mastered. This ‘learn on the job’ training with expert guidance is considered by many firms to be the most effective method of training, even compared to more formalized training courses. In addition to being effective for developing a collaborative relationship between the mentor and young engineer, it is also considered efficient from a billable hour stand point; however, the tradeoff here is the extra burden that it puts on the senior engineer.

A second approach that was cited by only a few interviewees involves use of previous projects. If a current project is to an extent similar to a past project, many firms will use this archived project to demonstrate the design process. The junior engineer can then use this past project as a sort of template or guide for designing the current project. Investing time to develop training materials from past projects would reduce the time requirement of senior engineers in the future while still providing junior engineers with expert advice embedded into stand-alone training resources. Interviewees from small firms found this investment infeasible since they do not hire engineers at a rate that would have a timely payoff and the evolution of the tools and techniques of the industry is such that the developed material would be obsolete within a short span of time. This is in many aspects analogous to challenges with developing educational innovations. While this approach does not seem a viable option for small firms, the interviews revealed that there is already evidence of this practice in larger engineering firms. Larger firms apparently have the need (large hiring rate) to justify development of such material and the resources in terms of time and manpower to maintain them. Many firms, however, proceed with caution when this training method is used because past projects often have assumptions or design criteria that may not be always applicable to a future project. Other training opportunities (e.g., online courses, participation in workshops, hiring a consultant to provide in-house training) were mentioned by several of the interviewees, but these were not frequently used due to cost factors.

Summary, Concluding Remarks, and Recommendations

Keeping pace with evidence-based instructional practices has been a challenge confronting STEM education. However, with today's technology-savvy students, and with the recent educational research on effective pedagogies, impactful solutions are beginning to emerge. In many STEM disciplines this is evident with packaging of multimedia content with traditional textbooks, the development of web-based and interactive material by publishing companies, and non-profit educational organizations that provide open-source educational content. In the field of water resources engineering education, recent efforts have focused on aspects such as the use of effective discipline-specific pedagogies (e.g., case-based and active learning approaches), incorporation of research and industry-standard tools and techniques through utilizing data and model-driven experiences, and collaborative efforts to develop a more unified curriculum. While such solutions are promising, resistance to adoption and implementation is still observed, which will eventually undermine the long-term sustainability of proposed educational innovations. To gain further insights into this critical problem, the current study engaged in an interview-based process through talking to potential customer segments (e.g., end-users and decision makers). The focus was on identifying key roadblocks and possible remedies that affect the successful development, adoption, and scaling of emerging innovations, such as faculty motivators and hindering factors, potential partnerships, industry perspectives on preparedness of recent graduates, and potential supporting resources.

The qualitative interviews of this study indicated that there is a lack of tangible motivators in place for faculty to engage in educational innovations. The way in which the universities evaluate professors, with different distributions of focus being allocated to effective instruction versus research productivity (Wagener et al. 2007), seems to play an important role in whether professors are willing to adopt new pedagogies. This suggests that achieving the desirable educational reforms in this field will largely remain in the hands of faculty members who are personally and professionally motivated to pursue such efforts. This was iterated by the interviewees who stated that self-esteem, self-efficacy, and desire for achievements in their careers as educators are the primary motivation for developing or considering the adoption of educational innovations. The results are in line with previous research on how instructors' decisions to engage in effective implementation of research-based instructional practices relies heavily on their instructional and personal preferences (Henderson et al. 2012). These results also highlight the importance of faculty development efforts in promoting sound pedagogical practices and learning theories in order to support effective adoption of innovations, as was recently suggested by Shekhar and Borrego (2016).

Results from interviews with hydrology and water resources engineering faculty members identified key hindering factors for developing and adopting educational innovations in the field (Table 1), including: time limitations, steep learning curves, continuous refurbishment, rigidity of material, locality of case studies to specific hydrologic basins and datasets, and lack of assessment tools and evaluation data. The first two of these factors were cited by a large majority of the interviewees. While the assessment data and tools factor was mentioned by only a few of the interviewees, its importance is evident in the existing literature. Assessment of innovative educational developments is an invaluable aspect of implementation and is critical to the successful scaling and adopting of innovations. These findings point out the importance of crucial, yet often-missing elements of user-support mechanisms to instructors who have the intention to adopt innovations. The expressed need for instructor support, both as built-in features of the innovation (e.g., rubrics, assessment methods) and as post-development support (e.g., follow-up support to resolve problems), agrees with the recently proposed model on design for sustained adoption (Henderson et al. 2015).

Results from interviews with practicing engineers in both private and public sectors revealed some critical information on the need for innovative resources that introduce data and modeling-based skills. Interviews with senior industry members indicated that young engineers have problems formulating solution procedures from context, lack familiarity with real-world hydrologic data, and have deficient knowledge of emerging analytic tools and modeling techniques that are increasingly used by industry to solve

Table 1. Barriers and proposed solutions to increase adoption of educational innovations in hydrology and water resources engineering.

Barriers to Adoption and Scaling	Recommended Solutions and Possible Opportunities
• Steep learning curves for instructors • Time requirements for development and implementation • Specificity of case studies to local basins • Rigidity of material • Lack of assessment data • Lack of assessment tools • Curriculum constraints • Lack of financial resources to sustain development • Refurbishing requirements	• Collaborative development and sharing • Modular design and customizability • Web-based developments to facilitate dissemination and adoption • Iterative and post-development faculty-support mechanisms • Assessment tools provided as part of the developments • Partnerships with water resources engineering industry • Educational initiatives at water resources engineering professional societies • Digital publishing

water resources problems. Young engineers acknowledged deficiencies in the use of computer models and their applicability within real-world hydrologic problems. While the interviewees did not reveal a specific reason for this problem, it is reasonable to attribute it to the lack of context and open-ended problems in traditional textbook problems.

Based on the views and insights gathered during this study, the following strategies for design and dissemination of new water resources engineering educational innovations are recommended (Table 1). To enhance the potential for broader adoption and scaling, educational material should be easily adaptable and flexible in nature, have mild learning curves (for instructors and students), and have a modular design to easily fit into current course curriculum that may already be crowded with existing content. Additionally, material should be consistently maintained and improved to keep up with the upgrading of models, data, and other technologies. Incompatibility of the structure, format, or content of educational innovations with existing work flow of the class requires extensive time and effort to overcome and often results in non-adoption. It is also critical that new material should be accompanied by a rigorous set of assessment resources (e.g., solution keys, rubrics) to encourage and support potential faculty adopters. The development of new educational materials without direct input from potential users often results in incompatibility problems and lack of user-supporting tools. An innovation development approach that is based on continuous and iterative feedback from potential faculty users holds a great potential for successful adoption (Khatri et al. 2016). Similarly, collaborative efforts and sharing of innovations and learning resources among universities can potentially result in the development of assessment data that encourage independent adoption as well as distributing the time and effort of development and upkeep. Furthermore, co-developed material that is well balanced between research specialties of the collaborators may present unprecedented opportunities for student learning. The need for long-term, post-development maintenance and user-support is undoubtedly challenged by lack of continuous streams of financial resources. The typical sources of funding that support educational innovations come from federal and state grants, which are by nature time-limited. This calls on the water resources educational community to look for non-conventional funding mechanisms. Avenues to explore include digital publishing of case-studies and associated datasets and models, possibly as supplements to textbooks or as standalone web resources. These opportunities are increasingly sought by other science and engineering fields and could potentially offer solutions for sustaining and growing the desired resources.

Talking with practicing professionals revealed many untapped resources which may be utilized by water resources engineering faculty through collaborations with industry practitioners. By contributing educationally-rich resources such as case studies, datasets, and existing models, industry can support instructors by easing the time and effort associated with developing educational innovations, and simultaneously contribute to molding the water resources engineering educational curriculum by introducing industry-relevant skills and expectations. Interestingly, there exist many similarities between developing and implementing educational innovations and professional training practices, e.g., refurbishing requirements of formal training resources and educational innovations; criteria for choosing training material and criteria for implementing educational innovations (time and convenience); and the use of web-based training courses and web-based technologies for university educational innovations. Despite constraints that might exist at the industry side (e.g., client confidentiality), studying these similarities can help identify parallel interests and challenges and inform efforts for investing in mutually beneficial academia-industry collaborations. Models of such collaborations exist in capstone classes, internships, and co-ops, and can be extended to other classes where data and modeling resources, for example, may be co-developed and used both by students and by junior engineers for early training purposes.

This research employed a qualitative approach using a sample of open-ended interviews with educators and professionals from different institution types and geographical distributions. The results can be further substantiated by adopting a mixed methods design (Creswell et al. 2003) where both qualitative and quantitative data are collected and analyzed according to the specific archetypes of the interviewees.

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