The Challenge of Change in Engineering Education: Is it the Diffusion of Innovations or Transformative Learning?

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Abstract—Development and dissemination perspectives based on diffusion of innovations theory are usually adopted as a change model for the broader adoption of evidence-based innovative educational practices. However efforts based on such perspectives have mostly not been successful in disseminating an educational innovation far and wide. We argue in this paper that the challenge of adopting and sustaining a new educational approach at a broader scale is an issue of the transformation of academics’ beliefs and values. Transformative learning theory provides a framework for change that is more appropriate for the nature of educational change. We provide a comparative analysis of diffusion of innovations and transformative learning theories and describe the nature of the challenge of educational change from the perspective of both theories.

Introduction

There is a sense of frustration in the engineering education community\(^1\) that despite a good awareness within the community for improved educational goals\(^2\) and practices\(^3\) and significant research based support for the effectiveness of such practices, the level of change in education is limited and slow\(^4,6\). The expectation is that innovative evidence based educational strategies should be institutionalized and disseminated\(^7\). The term innovation is frequently used for models or approaches of educational practice that have emerged as alternatives to prevalent educational practices. For example, a variety of educational approaches were presented in the plenary session of the 2011 ASEE annual conference. Examples of some of the approaches presented included active learning, formative assessment as a strategy to support learning, and problem-based learning. Each description of an approach included a summary of research-based evidence on specific educational impacts. The National Science Foundation, which funds projects for improving STEM education through its Course, Curriculum and Laboratory Improvement (CCLI) and Transforming Undergraduate Education in STEM (TUES) programs, has sponsored forums in which panels of practitioners and scholars were commissioned to investigate the issue of wider dissemination and scale-up of educational innovations\(^8,9\). These initiatives have used a development and dissemination model of diffusion of innovations to conceptualize the challenge of educational change. This is with the assumption that a new educational approach that has been empirically shown to be effective and superior to prevalent approaches should be adopted on a wider scale within the educational practice. The discussions at such forums revealed many complexities of transforming engineering education and the challenges of using a diffusion of innovations framework to understand the process of change in higher education.

The diffusion of innovations framework has a product-oriented view in which a product is produced at a source and propagated across a wider population through various channels of communication. Educational practices, however, are not well-defined routines such that they could be characterized as fixed and well-formed products. When two educators use the same educational approach what they share is a set of values and beliefs and not just a routine of practice. The most basic and prevalent approach of lecturing is not practiced as exactly the same routine by two different individuals or by the same individual in two different contexts. Adopting a new educational approach also means adopting a new set of beliefs and values. As a
theory, diffusion of innovations does not take into account the process of people transforming their beliefs and values. Beliefs and values are not a product of dissemination; rather individuals recognize them through experience. Transformative learning theory is specifically focused on understanding the process of revealing and challenging beliefs and values that happens with a change in practice. When we try to understand the impact of introducing an educational innovation, a more fundamental question that needs to be asked is how have people’s ways of thinking changed about good educational practice, and not just how much their practice has changed.

The purpose of this paper is to draw on the literature of social and human change with particular focus on the theories of diffusion of innovations and transformative learning to develop a compendious portrayal of the challenge of change in undergraduate engineering education. We compare the two theories and explore how each perspective provides insight into critical challenges of change in undergraduate engineering education. We do this in support of our argument that the challenge of adopting and sustaining a new educational approach at a broader scale is an issue of the transformation of academics’ beliefs and values, and therefore that the transformative learning perspective needs to be included in engineering education change initiatives.

We begin with briefly reviewing the historic background, salient conceptions and criticisms of these two theories. We then review goals for educational change that appear in recent literature, and describe the nature of educational change that may be involved in achieving those goals. Finally, we explore the challenge of educational change based on the two theories to frame the challenge at a deeper and more critical level. As we re-frame the problem we compare how the two theories differ and how they may possibly be complementary in facing the challenge of educational change by providing multiple points of view.

**Diffusion of innovations and educational change**

The school of thought of diffusionism emerged in the nineteenth century during the colonial era as an effort to understand how cultural traits spread from one culture to the other\(^{10-12}\). Diffusion as an anthropological theory, which stood against the evolutionary thought at that time, assumed that cultures usually seek to maintain the existing routines and discourage inventiveness. Here, major progress happens through the spread of ideas from a few cultural centers. The theory thus assumes that inventions can arise at one place and then are acquired by others through imitation\(^ {13}\). A number of concepts were proposed towards a theory of diffusionism. For example the concept of “cultural area” assumed that important traits typically originate at a center within an area and then spread from the center to the rest of the area. The diffusionist thought in anthropological research developed during a time when objectivist perspectives in scientific methods such as positivism, empiricism, rationalism, reductionism and later post-positivism were on the rise\(^ {14,15}\) and this paradigm underlies the theories and research on diffusion\(^ {16}\). Diffusion research historically grew within cultural anthropology and cultural geography. It was later adopted with pragmatic interests in areas such as agriculture business studies, education, political science and rural sociology to study how communities and societies can be brought around to adopt innovations\(^ {17}\) and how various factors influence the process of diffusion.
Rogers’s book on *Diffusion of Innovations*\(^{18}\) is the most comprehensive synthesis on the tradition of diffusion research. The first edition of the book was published in 1962\(^{19}\) which Rogers says he wrote to bring together the work on diffusion research among dispersed research groups and to develop greater awareness about the research\(^{18}\). In synthesizing the research he identified four main elements to the diffusion of innovations which are the innovation, communication channels, time, and a social system. He, therefore, describes diffusion as “the process by which an innovation is communicated through certain channels over time among the members of the social system.”

Within these four main elements, Rogers identifies the issues that have been in the focus for diffusion researchers. Diffusion research is mostly used with technological innovations where technology is conceptualized as\(^{18}\) “a design for instrumental action that reduces the uncertainty in the cause-effect relationship involved in achieving a desired outcome” (p 13). This description of technology indicates that the paradigm of diffusion research focuses on those innovations which have relatively well defined outcomes where one of the desired feature for the innovation is to reduce the uncertainty in the cause-effect relationship. This is in contrast to some of the innovative ideas and practices in contemporary education that call for open-ended student directed interactive learning\(^{20\text{-}23}\). Learning from this perspective is considered to be a non-linear process that has emergent outcomes without much focus on the cause-effect relationships within the process. Tangibility of innovation also seems to be important within the theory of diffusion of innovations. Rogers\(^ {18}\) notes that idea-only “software” innovations are not easy to trace because it is difficult to operationalize an idea-only construct such that it could be effectively observed for empirical investigation. In its early development, the use of the theory assumed that an innovation is adopted unaltered as it is diffused. However this assumption was refined over time and now the theory includes the concept of “re-invention” which is the degree to which an innovation is changed before an end user’s adoption. This recognition of re-invention as a possibility is important for educational innovations because it is not uncommon that new ideas in education are adapted or re-invented for their implementation in a given context\(^ {24}\). The main use of the theory seems to be in the adoption of “hardware” technologies that are not meant to be re-invented. The way re-invention has been discussed in the book\(^ {18}\) suggests that this issue is somewhat marginal to the main interests of the theory. As such, the pro-innovation bias is a recognized shortcoming of diffusion research\(^ {18}\).

One of the distinguishing features of the theory is its focus on “communication” in framing the problem of diffusion. Initially the theory involved a linear model of communication in which a message is assumed to be communicated from source to target\(^ {25}\). The theory now accounts for two-way communication in which participants share information to reach a mutual understanding. A communication channel is considered critical to communicate a message and interpersonal channels are considered more effective than mass media channels. *Homophily* is also a central concept of the theory in which the exchange of ideas occurs more frequently and rapidly when the two persons in communication are similar in attributes such as beliefs, education or social status. Thus communication is more likely to occur among people belonging to the same group or community. On the other hand *heterophily* is considered as one of the main problems for effective communication and thus for effective diffusion. For example, communication does not happen effectively when a change agent engages a client without knowing their interests and introduces an innovation to a client based on technical qualities that
are not of interest to the client. For communication to be effective, both participants in communication ideally should be homophilous on all variables except in relation to their knowledge about the innovation. Later in our discussion we explore effective communication as a challenge for educational change.

Including time as an element has allowed the theory to support some interesting concepts. The theory identifies steps of the process that someone goes through over time in making a decision for adopting or rejecting an innovation. Another concept is innovativeness which is the degree to which an early someone adopts an innovation. Five categories of innovativeness are (1) innovators (2) early adopters (3) early majority (4) late majority and (5) laggard. Diffusion research indicates that people within one category have considerable similarity with each other. Rate of adoption is another concept of the theory related to time. According to the model, the adoption of an innovation within a population is typically normally distributed such that the plot of adoption rates is S-shaped.

A social system is another important element associated with the theory of diffusion of innovations. The theory assumes that diffusion occurs within a social system which is bounded by shared common objectives. A structure or hierarchy within the social system is considered important for reducing uncertainty and improving predictability. Social networks are also recognized in the theory, which are formed when homophilous individuals stay in contact or group together. When regularized patterns of communication form within social networks the theory can predict individual behaviors and the likelihood of adopting an innovation. Diffusion researchers are particularly interested in studying the characteristics of a social system that facilitate or impede the diffusion of an innovation. For example, Spalter-Roth et al.\textsuperscript{26} studied a network of consumers and producers for a digital library of the scholarship of teaching and learning in sociology education. The study evaluated the likelihood of a diverse population of faculty to obtain material from the library and found that women, early career faculty, and faculty from non-research universities are more likely to buy material from the library. The study indicates that the launch of a digital library did not make a significant change on network behavior. In their study, they identified a core of 5 to 6% faculty members out of the whole network who were not only active participants in the activities of the network but also adopted leadership roles. Opinion leaders are considered important in the theory as they influence others in the social system in their attitude towards adopting an innovation.

The theory of diffusion uses social learning theory of Bandura as a way to describe how people learn in adopting an innovation as they socially come to know it through certain communication channels\textsuperscript{18}. This is a behaviorist perspective in which people learn by modeling and imitating others as a social process instead of critically assessing a given innovation. This limits the usefulness of the theory of diffusion in describing the adoption of innovations that cannot be learned through simple modeling. Some researchers have attempted to extend the theory by associating knowledge based and complexity approaches with the diffusion of innovations model\textsuperscript{27}. From knowledge based perspective the more prior knowledge people have relevant to making sense of the new knowledge, the more likely is the diffusion of knowledge. Similarly, complexity requires embracing uncertainty as part of the process of adopting new ideas, which is in contrast to the conventional inclination of the diffusion model towards reducing uncertainty. Such an extension to the theory also means moving beyond the quantitative generalization-
seeking research that is prevalent with diffusion research to qualitative contextually-focused research in studying the diffusion of new ideas. Some have investigated diffusion of knowledge\textsuperscript{28} as an alternative to the diffusion of innovations model for investigating the diffusion of new ideas, which supports taking an emergent complexity-based perspective towards diffusion.

A critique for the diffusion of innovation model and research is that it has been developed with a focus on the adoption of an innovation by individuals and does not apply as effectively for the diffusion within and across organizations\textsuperscript{29}. Some critics question the fundamental premise of the diffusion paradigm that an innovation should be seen as something that originates from one place and it then spreads to a passively receiving community\textsuperscript{30}. Ways to address this argument involve moving to a perspective in which innovation is considered to be an interactive process as a partnership between researchers and practitioners.

**Transformative learning in educational change**

Transformation is a fundamental aspect of human life. From childhood we develop our beliefs about certain assumptions based on our life experiences and through the influence of social norms and culture. As our beliefs get reinforced we use them unconsciously for making decisions while we are consumed in our day-to-day life. A transformative change is a change which requires examining some of our fundamental assumptions that form the basis of how we think, how we act and how we think about ourselves for who we are and what we want to be. The process of transformation involves a significant change in our mindsets, our worldviews and our sense of self. Transformation is a form of learning that is distinguished from learning new knowledge or skills\textsuperscript{31}. For example, Piaget’s cognitive constructivist theory provides a model for learning according to which any new idea we come to know cumulatively assimilates with or accommodates within the structure of what we already know. Transformation is often a profound learning experience which involves a simultaneous and extensive restructuring in what we have, do or are cognitively, emotionally and socially.

As visionaries of educational change such as Dewey and Scheffler called for a holistic education\textsuperscript{32} and teaching informed by theory\textsuperscript{33,34} and learning theorists increasingly emphasized a constructivist approach to learning\textsuperscript{35–39}, several investigators have studied how educators think about such ideas and bring these ideas into their practice. Towards this end Shulman proposed several categories of teacher knowledge\textsuperscript{40} that any teacher would need to perform effectively. Two of these categories are knowledge of the content of the subject and knowledge of pedagogy. Here, teaching knowledge is not just a matter of following and applying knowledge in prescribed ways. Rather a teacher needs to be able to skillfully use the knowledge base for making decisions appropriate for the goals of a learning task, the learning context, and the students. This is the competency of a teacher in the conceptions and practice of teaching. The strategies that teachers adopt are also determined by their philosophies for knowledge and education or what Trigwell & Prosser\textsuperscript{41} call as intentions for teaching. Conventional teaching is often carried out based on a transmission perspective for learning\textsuperscript{42,43} in which a teacher uses a content-focused strategy with an intention of transmitting the information to the students. Someone with a more comprehensive perspective of teaching may adopt student-centered strategies\textsuperscript{44} with an intention of either students’ conceptual development, student competency development, nurturing students
to develop their personal agency, or awakening and transforming students values and ideologies to be effective citizens in the society. Recognizing the importance of teachers’ beliefs, researchers have investigated teachers’ epistemological and ontological worldviews. In particular, research on teachers’ beliefs indicates that teaching practice is closely related to teaching conceptions and beliefs about knowledge, education and teaching. It follows from such observations that changing beliefs and conceptions of teaching are critical for any substantive change in teaching. Efforts to influence beliefs through courses and interventions that seek to challenge individual beliefs have mixed outcomes. De-contextualized evidence-based teaching models that are prevalent in the literature have also been shown to offer limited support for teachers to change their practice. Many researchers consider reflective practice, in which a teacher frequently engages in reflection on their ongoing practical experiences, as having more potential in helping practicing teachers change their beliefs. For example, a study of teachers’ narratives indicates that the participants developed more sophisticated conceptions of teaching by engaging in reflection on their everyday teaching experiences, and that emotions played a noticeable role in this process. This in turn was found to impact teaching practice and the development of teaching knowledge.

A theory that could help describe the learning associated with teachers changing their practice along with their teaching conceptions and beliefs can be very valuable in understanding the challenges and possibilities within the process. Among the theories of adult learning, a theory that focuses on changes of beliefs and values is the theory of transformative learning. Early framings of this theory were based on Jack Mezirow’s study of perspective transformation of women returning to community colleges in 1970s in the US. Transformative theory focuses on the learning that is associated with adults taking a critical stance towards an issue of our attention and as a consequence “reassessing the structures of assumptions and expectations which frame our thinking, feeling and acting” (p 24). Mezirow calls the structures of our assumptions “frame of reference” that get reified over time as we use them automatically and uncritically to make meaning of our experiences and reject ideas that do not fit well within our preconceptions. At a generalized level, a frame of reference is constituted as a system of coherent assumptions in relation to sociolingual, epistemic, moral-ethical, psychological, aesthetic and other such philosophical questions. In other words it is a system of our assumptions that are our answers to such questions as what do I believe about myself, what are social norms, what are my values, why are my values important, and how do I know that something is true. The theory is grounded in the constructivist paradigm which focuses on how humans construct the meaning of their experiences. Unlike the paradigm of diffusion of innovations, which seeks predictability and reduction of uncertainty, in transformative learning theory emergence and uncertainty are embraced as characteristic of the transformation process. The theory also focuses on communicative learning as distinguished from instrumental learning. In instrumental learning an assertion can be validated through empirical evidence; in communicative learning we develop beliefs, values, and feelings in communication with others which we achieve through mutual meaning making rather than based on explicit empirical evidence. “Discourse” is an important component of the theory – it is the means for anyone to validate what is communicated and to find convergence within a negotiation. One of the
competencies for a learner to participate in discourse is the ability to negotiate their current values and meaning rather than to simply act on others. Like the theory of diffusion of innovation, communication is an important element of the theory of transformative learning. However, where diffusion theory is interested in top-down communication, the communication in transformative theory is mutual and collaborative. In other words, the potential for a communication between an educational researcher and a practicing teacher to be transformative is as much for the researcher as it is for the practitioner. Mezirow\(^60\) considers becoming rationally critical as a necessary condition for a discourse or an experience to be transformational. Thus, the theory highlights the role of critical discourse and critical reflection in the transformational process. Critical discourse refers to the critical assessment of assumptions as discourse as two or more individuals come to a common understanding. Critical reflection refers to reflecting on assumptions for their validity as they are used to construct meaning from experiences. The outcome of the transformation process is becoming aware of our tacit assumptions and assessing them for their validity. As a consequence\(^64\), “transformative learners move toward a frame of reference that is more inclusive, discriminating, self-reflective, and integrative of experience” (p 5). The theory has also received criticism. Mezirow’s conceptualization of transformative learning has been criticized for placing too much emphasis on rational reflection and not giving due consideration to the role of emotions in transformation\(^65,66\). Newman\(^67\) has even questioned if transformation is a phenomenon that can be identified such that it could be distinguished as a form of learning. The movement of transformative learning that Mezirow founded, has resulted in a large number of studies and publications with a variety of perspectives on the theory and the people working with the theory consider it a theory in progress\(^68\).

Because communication and social interaction are elements of transformative learning theory, there have been studies that look at transformative learning in groups and organizational settings. Organizational change that requires a transformational shift in the structures, processes and practices of the organization is considered unlikely to be achieved without organizational members going through transformative learning so they may function effectively within the new goals and realities of the organization\(^69\). Constructivist and transformative approaches have been argued to be more effective for the kind of education intended to develop practice in an organization\(^70\). Such educational approaches link practice, context and knowledge into an integrated learning system. Situating learning within the context of a cohort collaborating on real life work can provide significant transformational learning experiences\(^71,72\). Even the adoption of technology in education can be more than just learning the use of technology and may involve teachers experiencing significant perspective transformation\(^73\). Other research based educational ideas require a comprehensive transformation of feeling, values and beliefs for the utilization of ideas in practice\(^74,75\).

The goals and nature of change in engineering education

Before exploring the challenge of change we should first take stock of the nature of change as it relates to goals for change in engineering education. Depending on the theory of change we adopt, there can be several ways to conceptualize and approach problems associated with particular goals for change. In this paper we have been focusing on two specific models, diffusion of innovations and transformative learning. The former focuses on the impact of
communicating a message for an innovative idea on the practice and behaviors of individuals. The latter provides a framework for conceptualizing how individuals come to transform their system of beliefs, values and feelings as a process involving experiences, discourse and reflection. In this section, we examine the nature of change in order to determine if it is more fitting to model educational change as a matter of communicating a new idea to adopt in practice or if it is critical to consider a change in individual beliefs.

The goals of education are fundamental to shaping a system of education. By goals we mean both the goals in their explicitly stated form as well as how participants and beneficiaries of an educational process perceive the implicit goals of education. Educational goals are shaped by how participants of the process conceptualize knowledge and learning within a discipline and by explicit and implicit expectations regarding the educational process. Furthermore, the structure that supports the educational process, which is often expressed through the curriculum, is a critical aspect of an overall education system. Finally, the educational process or practice, which consists of instruction and assessment approaches, is also an important aspect of an educational system. Faculty members, as participants of an educational system, have considerable influence as they are deeply involved in making decisions regarding educational goals, structures and processes.

An educational change may involve change in just one aspect or a simultaneous change in all the three aspects of an education system. Among the various arguments for educational change found in the literature, some question the quality of education and seek only a pedagogical change, i.e., a change in educational practice without a change in educational goals or structures. One example of this is incorporating student-centered pedagogies within regular classroom practices. On the other hand, the National Academy of Engineering’s report on “Educating the Engineer of 2020”, puts forth a revision to broad educational goals in which the purpose of educating engineers is not just for students to master disciplinary knowledge but also to become socially aware, take up societal challenges, and be flexible and adaptive to evolving local and global realities. Other educational problems, which include underrepresentation of minorities and the shortfall of students graduating from STEM disciplines, may need to revise one or more of the three educational system aspects of goals, structures, or practices to make education more relevant and engaging for students.

Therefore, there are multiple grounds on which arguments for change in engineering education are made. As Kezar notes, one challenge of educational change is that there are too many change initiatives that are being pursued in higher education. Many of these educational goals may appear unrelated but are actually connected and complementary to each other. For example, bringing real life experiences into education has both a pedagogical value while supporting a goal of increasing student interest and motivation. Adams et al. use the word “entwinement” to describe how multiple goals of education of student engagement, their learning for knowing and becoming, their development of technical and social awareness, and the diversity and inclusiveness in STEM education all might be interrelated to each other. A well entwined system of education forms when goals, structures and processes of an educational system are well synchronized and aligned through a single paradigm. Therefore when we have a goal of educational change the question arises that if our goal can be accommodated in the prevalent functioning paradigm. The beliefs and commitments that the members of an educational
organization hold based on the prevailing paradigm for themselves and for their existing ways of thinking and acting might be in conflict with desired goals for change. When change involves a change of paradigm, transformative learning may be necessary. Because of this, it is important to make explicit for ourselves the nature of our existing beliefs and practice in order to understand how our existing worldview relates to a change that we are seeking.

Let us take the example of a simple pedagogical change for engaging students such as using a brief active-learning activity within a classroom as part of a regular lecture. In comparison to more elaborate innovative teaching models such as inductive approaches of inquiry learning or problem-based learning, this is a relatively modest educational change. Even so, bringing a simple active learning strategy within a lecture may require a paradigm shift for a teacher who is used to exclusively practicing one-way lecturing. When teachers are introduced to active learning strategies for classroom many teachers quickly recognize the value of the strategies in engaging students. However, they find it difficult to envision how this can be brought into practice with their competing concerns for time management, control of classroom and managing student expectations. Many may feel that engaging students is a helpful but not critical task for them within their role as a teacher. They may continue to assume that their primary teaching responsibility is to cover the content and that the most efficient and effective means for doing this is through lecturing students on the content. The paradigm shift for this “simple” change involves moving to a constructivist perspective for teaching and learning and is well documented in the literature. Biggs and Tang, for example, identify three levels of shifts in the conception for teaching. Teachers, at the first level, consider that their responsibility is to know their content well and to be able to expound the content clearly to the students. They attribute differences in learning to students’ abilities and motivation. The focus of a teacher at level 2 shifts from students’ abilities and motivation to what they do as a teacher. They still consider their responsibility to transmit content but become conscious for how they can effectively get the point across. They use a variety of strategies but the focus is on what they do as a teacher and not so much on what students do for their own learning. Level 3 is the student-centered perspective for teaching where the teacher focuses on what a student does for their own learning. Prawat similarly provides an elaborate set of assumptions that a teacher might have to overcome to move to a constructivist paradigm. Samuelowicz and Bain compared different classifications of teaching conceptions. They found differences in intermediate levels but all classifications show a shift from a transmission model to a student-centered model of teaching.

An educational change aimed at making a fundamental shift in the goals of education is not limited to a transformation in teaching conceptions alone. Palmer and Zajonc, for example, propose a fundamental shift in how we envision the purpose and outcomes of higher education. They challenged the current focus of higher education on empiricism and rationalism with its associated perspective on human learning as learning how to obtain and work with empirical data or use logic to model and understand our reality. Instead, they argue that learning, in a holistic sense, also includes bodily knowledge, intuition, imagination, and aesthetic sensibility. Their vision of an integrative education requires a substantial paradigmatic shift over multiple dimensions: ontological, epistemological, pedagogical, and ethical. When contextualized for the case of engineering education, this idea comes close to the vision of educating the engineer of 2020. Realizing this vision requires an ontological shift in assuming the structure of nature from a mechanistic perspective to a relational perspective of seeing elements in the structure of
nature as interdependent and interwoven. The associated shift in the structure of curriculum moves from a fragmented and competitive structure toward one that is holistically interconnected, integrated and collaborative. Epistemologically, the premise of an integrative education is that of a knower that is communally in connection with reality rather than separated from it. It is a move from an illusion of absolute objectivity to a contextual objectivity that is assumed to be relative to the context of the community. This assumption means that we know something by being in relation to it rather than by being separated from it. Therefore, an integrative education is based on concrete and contextual experiences rather than abstract and de-contextualized lessons. The pedagogy shaped from this ontology and epistemology is one of establishing relationships of students with content, with the teacher, and with other students rather than one of isolating students as empty vessels that need to be filled with information. The ethics of an integrative education is that of a moral engagement with what is being known rather than maintaining a distance to avoid any influence. The scope of such a paradigmatic shift may seem extensive and far-reaching but is fully relevant to what we already recognize as components of the 21st century engineering education87. Making this shift can take us to a new educational reality in which all the goals of educational change currently on our agenda will be achieved entwined with each other in a single integrated system.

The kind of paradigmatic shifts discussed above are immensely challenging to operationalize in practice. While the literature offers many evidence-based practices, it is rare that these practices may be applied without significant adaptation so that they are appropriate for a specific context. The required transformation may require that teachers experiment with new perspectives on education and student learning over a long period and iteratively learn through reflecting on their practice. When adopting new educational ideas teachers need to make decisions on how they can find a balance between giving students more contextual and integrated learning experiences and making sure that students are adequately exposed to the abstract concepts of a subject. Teachers need to discover the tacit assumptions behind the knowledge and practice of their discipline to be able to adopt a pedagogical approach that is appropriate for the instruction of subject-matter and students’ backgrounds. An education that focuses on engaging students and providing them with contextualized and personalized learning experiences is much less structured and in control than a transmission model of instruction. The teacher needs to know how students can learn communally within such a classroom environment and how to establish and manage the associated classroom culture. Another paradigm shift for teachers who are used to standardized norm-referenced summative assessments is to assess students using rich qualitative feedback aligned with the notion of integrative education and to reframe assessment as a critical component of the overall learning experience for students.

The challenge of change: framing the problem

Discussions on the challenge of change often revolve around finding solutions to overcome perceived challenges. A key assertion of this paper is that we need to discuss and explore how the problem of educational change could be framed before searching for possible solution strategies. The question becomes: how we can frame the problem of educational change so that it will empower us to adequately understand the challenges of educational change? The way the problem is conceptualized and defined determines the approach for solving the problem. For example, transmission and constructivist conceptions of the process of learning were described
in the previous section as two different framings for conceptualizing the problem of learning. Each leads to different orientations for designing instructional approaches to address student learning. Re-framing the problem of educational change can open up new (and potentially disruptive or counterintuitive) insights, which were not previously available. In this section, we take a deeper look into the issue of transforming education to explore other problem framings and their potential impact or success.

The adoption of the diffusion of innovations theory to understand the transformation of educational practices on a large scale seems to be based on an implicit assumption that educational innovations are products that are produced and tested. It is assumed that teachers will adopt innovative educational practices if they are provided with evidence of the effectiveness of these practices over existing practices. Once the concept of the new practice is effectively communicated to the teachers they should be able to adopt the practice. Using the diffusion of innovations theory provides a conceptualization of the challenge of change that influences thinking about how to look at the problem and imagine possible solutions. In examining a situation in which the diffusion of an innovation failed (pp 4–5), Rogers \(^{18}\) notes that adoption rates are influenced by the compatibility of an innovation with the values and beliefs of individuals in that social system. However the theory does not address the issue of the transformation of values and beliefs, rather, with its empirical bias, it focuses on the social process of interpersonal communication. In other words, the innovation-decision process is conceptualized as a linear process with two outcomes of either acceptance or rejection. The theory does not consider the process of critical meaning making that might be associated with making a decision and adopting an innovation.

In the previous section we explored the nature of educational change and argued that a desired educational context and practice may be situated in a paradigm that is different from our existing paradigm. As Kuhn \(^{88}\) described, a paradigm is established based on a perspective or a belief system that a community accepts as a premise for looking at and constructing their reality. The community uses this premise as a foundation for cumulatively extending their enterprise. In addition to a premise, a paradigm consists of problem solving models and routines of practice that community members emulate to solve problems of common interest to the community. Several community members may embrace and master the practice without developing an explicit awareness for the premise of the paradigm and therefore have only a tacit sense of the guiding premise. As a community develops around a paradigm it constructs a social reality that the members become intuitively situated within and feel convinced that this is the way a reality can exist. Any alternate possibilities outside the norms and beliefs of the paradigm will seem counter-intuitive and unconvincing to the members of the community. Bourdieu \(^{89}\) uses the term *habitus* for such a state, which he describes as a system of durable dispositions that members of a community come to adopt based on their social experiences and use them to regulate their practice without conscious aiming. A change proposition that is compatible with the paradigm will accumulate relatively easily into the existing practice of the community. In contrast, a change proposition that is in conflict with or challenges the basic premise or models of practice of the prevailing paradigm will not be accumulated without a systemic transformation. A transformational change is one that is “outside-the-box” or outside the established paradigm. When realities within an environment shift or a social reality evolves, this may lead to the emergence of disruptions within a community that cannot be reconciled in the existing paradigm.
A transformational process could be initiated if some members of the community recognize and highlight the importance of resolving such anomalies. However, the overall community might appreciate the need to resolve the anomalies but find it difficult to address the issues within their existing beliefs and ways of thinking and acting. Such a situation occurs when our existing beliefs and practices are situated in a paradigm that is different from the paradigm associated with a desired goal for change. It is this kind of situation that requires us to deconstruct and disentangle our existing socially constructed reality, gain awareness of our implicit assumptions, and reweave the social complex through a revised premise that can entwine systemic goals, structures and processes.

Mezirow’s transformative learning theory uses the conceptions of “perspective transformation,” “frame of reference,” “meaning perspective” and “habit of mind” to relate to Kuhn’s conception of paradigms. The theory then builds on Freire’s critical pedagogy and Habermas’s theory of communicative action to conceptualize how adults come to find a new perspective beyond what was available to them in their existing paradigm. Both transformative learning and diffusion of innovations theories consider communication as a critical element for change. The role of communication in both theories, however, is significantly different. Diffusion of innovations theory considers communication channels as a critical means of informing individuals within a social system about a new idea and persuading them to adopt the idea. In contrast, transformative learning is interested in the transformation of individuals within a social system where communication plays a role for achieving a transformation through a process of critical discourse. The participants of the discourse critically assess their commonly held assumptions to find a new mutual perspective and redefine the models of practice within their paradigm.

Diffusion of innovations theory considers that the social influence and affinity of the person who communicates a new idea to other people mainly determines people accepting or rejecting new ideas. Transformative learning theory assumes that people find difficulty in accepting new ideas when they are not able to see the meaning of an idea within their existing frames of reference. The two theories adopt different point of views in diagnosing the problem of accepting a new idea which makes them complementary in the sense that the strategies can be combined.

Diffusion theory can guide in inquiring into people’s attention towards a new idea while transformative learning theory can guide in inquiring into people’s critical assessment of their assumptions as they become aware of new ideas.

In the discussion above we made a distinction between informational and transformational learning. The former includes becoming familiar with new ideas and learning new techniques and skills. This is the kind of learning in which learners assimilate or accommodate new ideas for thinking and acting without significantly altering their existing belief systems. In the latter, the composition, structure or even the basic character of our existing assumptions and belief system may transform. We assume that solving the problem of educational change may require both informational and transformational learning. The overall educational change is often an iterative process such that informational and transformational learning go hand in hand, complementing each other. This process may be initiated when we come to know or experience something new that, based on our existing assumption, looks interesting to us and catches our attention such that we want to learn how to act upon that new idea. If, however, we are not successful in effectively making sense of that new idea without critically examining our existing system of habits and beliefs then the existing system may need to undergo transformation in
order to support the new ways of thinking and acting that we want to adopt. Thus the awareness of a new idea focuses our attention towards experimenting with that idea, which may ultimately lead to reexamining our beliefs if the new idea cannot be accommodated within an existing system of beliefs. This transforms our belief system into a new level that enables us to find a new set of interesting ideas that were not meaningful to us before. Therefore, the overall process of change consists of interactions between the revision of belief systems and the development of new competencies for a revised practice. This is often best achieved as reflective practice. Epistemological differences between educational research and educational practice make it difficult to readily bring research-based knowledge into practice. Fullan argues that we often rely too much on theory and that using common sense and our contextualized knowledge can be much more effective in finding a good approach for moving forward. A good environment for enabling improvements in teaching practice is to let teachers grapple with the problem solving process and provide them a safe place and support to address their concerns. In particular, teachers need opportunities to deconstruct their old system of beliefs and practice and to go through cycles of embodied experiences with feedback in order to find a compatible combination of revised practices and a revised belief system.

As we described the notions of paradigm above we noted that members of a community often unconsciously follow the routine practices of their paradigm without an awareness of the premise on which the practices function. Some of the very basic assumptions behind our actions become so habitual that these assumptions take a hold on us. We become subjected to these deeply operationalized beliefs such that these beliefs drive our thinking and actions. The metaphor of “lens” is sometimes used to describe how we use our belief system without a conscious awareness. If we can imagine our belief systems as lenses through which we see the world, then we can understand how we interpret our experiences through our beliefs. For example, for those who have to regularly use prescription glasses, glasses become so much a part of their life that they may lose the conscious awareness that they are using glasses. The glasses may even become part of their identity. Recognizing that it may be time to have one’s vision examined may occur, for example, when they encounter a situation that compares their vision with someone else’s vision. Similarly, our beliefs, which we become subjected to, need to be revealed to us and we need to become aware of them in order for us to be able to critically examine and potentially revise these beliefs. As such, the real challenge of transformative learning is to become aware of deeply held assumptions and to be able to refine them to make them more inclusive of other perspectives.

When a problem is one that requires transformational learning but is treated as a problem of informational learning, then the solutions posed are not likely to be effective. Either the effort of telling others of what new behaviors need to be adopted is completely ignored or the new behavior is adopted in a superficial manner that is not sustainable. In these cases the problem was misdiagnosed as an issue of informational learning rather than one of transformative learning. The point to recognize is that classifying the problem as a lack of adequate practice can be an insufficient investigation of the problem. We need to go behind the apparent behaviors to reveal the belief system that is driving those behaviors.
Facilitating transformative learning

The main purpose of this paper is to highlight a need for reframing the problem of educational change. This was done by conducting a comparative analysis of two distinct theories, and presenting an argument for how the theory of transformative learning may provide a more productive and substantive framing of the problem of educational change than diffusion of innovation theory. In the remaining paragraphs we present a brief review of some possible directions for facilitating change from a transformative learning perspective.

Some of the most radical transformational experiences are often emergent personal processes rather than intentionally facilitated. There are, however, several approaches which one can adopt to foster transformative learning within a social context and within individuals. Mezirow has identified ten phases that one may experience as part of transformation. A “disorienting dilemma” is the beginning phase, which is often externally stimulated. The remaining phases involve a person actively thinking, acting, feeling or participating as they go through the process. The process is, therefore, highly “learner-centered” and any effort for transformative learning has to be such that it facilitates learners to be actively engaged towards a transformation. Asking questions and telling narratives have been considered to be effective ways to bring learners into a state where they can engage in figuring out an issue on their own. Learning can then be facilitated by creating a supportive space and facilitating interpersonal connections that stimulate critical reflection.

Programs focused on adult transformation with a long enough duration can bring about a significant transformation in individuals broadening their point of view and forming a strong identity for a particular goal. Undergraduate and graduate programs have been shown to be significantly transformational for students both in the traditional format as well as formats specifically designed from a transformative learning perspective. Faculty development masters degree and certificate programs have been designed to provide thorough experiences for higher education teachers to develop their knowledge of pedagogy and their skills as teachers. These programs provide a well-supported environment for teachers to develop the confidence to adopt constructivist pedagogies and evidence-based practices. The alternative to such programs is to adopt lifelong learning approaches as intentional learners who reflect on their practices and engage in discourse within communities.

Faculty learning communities are considered one of the most promising approaches for faculty to engage in exploring novel conceptions and methods for teaching and learning. Communities are established based on a commitment to interact frequently and with a purpose of supporting each other in mutual transformation. A community is usually cross-disciplinary to bring diversity and increase transformational potential. Learning communities are of limited size to ensure strong collaboration and interaction and may stay together from several months to possibly several years. They can be institutionally supported such as having regularly organized seminars or other developmental activities. Community members bring their projects to get feedback and ideas, and for keeping tasks on target in a trustful and safe environment. Learning communities have been found to be effective in helping faculty members develop a deeper pedagogical perspective for developing their teaching practice. By participating in the communities they widen their perspectives for integrated curriculum and aligning instruction and
assessment to address developmental learning outcomes. Teachers may also engage in communities with an interest in the scholarship of teaching and learning (SoTL)\textsuperscript{44}.

Learning community is a participatory group learning approach. Some other variants include Action Learning and Collaborative Inquiry\textsuperscript{104}. In action learning, participants work in small groups to solve a real world problem and engage in reflective practice as a way to learn. Collaborative inquiry centers on a question that is important for a group of people to answer, and the group engages in repeated episodes of reflection and action to find an answer to the question. Yorks and Marsick\textsuperscript{104} categorized the literature on action learning over four levels. At the most basic level the assumption is that people coming together to address a problem leads to significant learning. There is no specific role and consideration for reflection at this level. The second level involves reflection with a focus on the outcome or content of the solution that was developed. At the third level not only the content but the process of developing a solution becomes the focus of reflection. At the fourth and the highest level, reflection supports critical assessment of the premise along with the content and process of solution. With each level the possibility of having deeper transformation increases. At the same time the learning process becomes more critical and complex. The possibility of participants becoming aware of their deeply held assumptions is highest within the fourth level action learning.

Many of these collaborative approaches do not attempt to explicitly uncover and make us consciously aware of our assumptions that drive our thinking and acting, and hold us back from making a change. Kegan and Lahey\textsuperscript{105} consider assumptions that have a hold on us to underlie our “immunity to change.” This is on the premise that we have commitments to our existing ways of thinking and acting that compete with efforts to move towards achieving new goals for change. Kegan and Lahey have developed a protocol to uncover one’s immune system, which is holding them from achieving a change goal for which they have a high sense of commitment. One can follow the protocol on their own or under the facilitation of a coach to reflect upon and identify “hidden competing commitments” and “big assumptions.” One can then plan experiments to test these big assumptions in order to challenge their validity, which can help them get released from the hold of those assumptions. Burton, Schlemer, and Vanasupa\textsuperscript{106} have also proposed a protocol for self-observation and action research to interrupt current routines of practice and to gain awareness of unconscious routines and assumptions for transformational innovation in engineering education.

**Conclusion**

It has been observed in previous publications that dissemination efforts for innovative educational practices based on the diffusion of innovations theory have not been very successful\textsuperscript{7,107–109}. Kezar\textsuperscript{103} shared her experience of participating in National Science Foundation (NSF) meetings to discuss scaling-up the adoption of STEM education innovations through dissemination. She writes about the meeting that, “we ended up with more questions than solutions” (p 236). The authors of this paper participated in a meeting\textsuperscript{9} organized by the National Academy of Engineering (NAE) which was to discuss the diffusion of transformative engineering education innovations and had a similar experience. When we attempt to explore a solution to a problem and this process leads to more questions, then this may be an indicator that
the problem is not well understood and that there is room for delving deeper into understanding
and reframing the problem. This paper is our effort to frame the problem at a deeper level that
may be at the core of why change is so difficult. We have presented an argument that many of
the goals of educational change that have been difficult to achieve are those which entail a
paradigm shift. Such a change can be framed with the help of the theory of transformative
learning as transformative learning is a condition for a paradigmatic transformational change.
This theory conceptualizes the collective transformation as an emergent collaborative process
within a community and highlights the roles of critical reflection and critical discourse within the
process. The deeper learning achieved through this critical assessment of assumptions is not
accounted for in the diffusion of innovation model. Using transformative learning theory to
understand the process of educational transformation is necessary but perhaps not sufficient.
One usually recognizes new perspectives for teaching and learning on having concrete
experiences of the functional models of teaching and learning based on those perspectives.
Therefore, we may also need to find theories that could help us recognize opportunities within
existing educational contexts and ways to support experimenting with new educational ideas.
Regardless, adopting a transformative learning perspective for educational change can be helpful
in examining fundamental questions about what facilitates or inhibits the kinds of shift in
thinking that are necessary for educational transformation. It can provide a new direction for
investigating the central question raised at the NAE meeting: “How does engineering education
change occur?”

Government and other funding organizations are very interested in understanding how research-
based ideas, which have been developed with their sponsorship, are disseminated and
implemented across contexts and over a large scale. Diffusion of innovations seems fitting
as a guiding theory for the purpose. However transformative learning theory is better-suited for
the emergent participant-centered and mutually collaborative nature of educational change that is
not easily understood or addressed through dissemination models for change. Zemsky’s lessons
from experience align well with a view of educational change through a transformative
learning theory lens: “strong rhetoric changes nothing—not even a strongly worded indictment
based on what the reformers believe is overwhelming evidence” rather he suggests “promote
conditions and circumstances that make most if not all institutions rethink first their assumptions
and then their operations” (p 208). Tagg uses the word “endowment” to refer to the prevalent
value system, which supports certain matters more, such as basing promotion, and tenure
decisions on disciplinary research. We also agree with his suggestion to “stop creating strong
anti-change endowments” (p 14) that favor sustaining prevailing practices and to support values
which encourage people for being enterprising in exploring and experimenting for educational
change. Boyce says “the challenge of successful change is less planning and implementing
and more developing and sustaining new ways of seeing, deciding, and acting” (p 133).
Underlying these new ways are values that are enacted throughout a system.
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