Full Paper

Motivation

In the social and political context of increased accountability and limited support for research and developments (R&D), engineering education researchers and practitioners are being asked to identify the tangible impacts of their work. However, this is not just an issue for the engineering education community. More broadly speaking, the value of research is being scrutinized because its importance is not well understood by society, and research is often considered to have no practical significance (Bornmann & Marx, 2014; Petit, 2004; Salter & Martin, 2001; Smith, 1997; Ziman, 2000). This issue is exasperated by the dearth of scholarship on how impact should be defined, characterized, and evaluated—both in general, and in the context of engineering education (London, 2014). This context of more questions than answers about research impact, and the need to wisely allocate resources to support it creates a very competitive environment for researchers asking for federal support of their R&D activities. Thus, it is imperative that researchers to make stronger cases defending the link between their research and the national priorities driving the funding activities of the agency supporting it.

When asked to respond to inquiries about the societal impact of their work, researchers tend to express one of two reactions: feelings of disinterest or feelings of inadequacy (Bornmann, 2013; Holbrook & Frodeman, 2011; Spaapen, Dijstelbloem, & Wamelink, 2007). "Scientists generally dislike impact considerations, which they often see as challenging their authority and undermining the autonomy of the scientific enterprise" (Holbrook & Frodeman, 2011, p. 244). On the other hand, some researchers do not feel they have adequate expertise to articulate the societal impact of their research; they perceive these requests are beyond their disciplinary expertise (Holbrook & Frodeman, 2011). Recent studies indicate, however, that researchers are not alone in their struggle to conceptualize and communicate impact.

Research impact includes two facets: scientific impact and societal impact. *Scientific impact* refers to advances in reliable knowledge (theories, methodologies, models, and facts) that primarily influence academic communities (Bornmann, 2013; Bornmann & Marx, 2014; Donovan, 2011; Godin & Doré, 2005). By definition, the primary beneficiaries of scientific impact are members of academic communities and the scale of scientific impact is confined to academic circles. *Societal impact,* on the other hand, is broadly conceived as research that influences social, cultural, environmental/natural, or economic capital of a nation (Bornmann, 2013; Bornmann & Marx, 2014; Donovan, 2011). Examples of this might include: stimulating new approaches to social issues; informing policy; improving our understanding of how we relate to one another's society and culture; reducing waste and pollution; and increasing productivity (Bornmann, 2013). While these two facets of research impact are widely accepted among research impact scholars, there are many unresolved issues with characterizing and studying the impact of research. Existing literature on research impact includes a myriad of difficulties associated with studying the impact of research. However, a synthesis of this literature has resulted in three categorizations across three headings: difficulties associated with connecting impact with research or the researcher; difficulties associated with assessment and evaluation; and difficulties associated with interpretations of impact. This purpose of this paper is to start a more sophisticated conversation about the impact of research in the engineering education community by providing a synthesis of the difficulties associated with studying research and proposing next steps for advancing the field of engineering education's collective understanding of impact.

Three Difficulties Associated with Studying Research Impact

Difficulties Associated with Connecting Impact with Research or the Researcher

The *attribution problem* is one of the most commonly cited reasons why studying impact is so difficult (Bornmann, 2013; Godin & Doré, 2005; Grant, Brutscher, Kirk, Butler, & Wooding, 2010; Martin, 2007; Rymer, 2011; Scott, Blasinsky, Dufour, Mandai, & Philogene, 2011; Spaapen & van Drooge, 2011). This is the difficulty with attributing impact to particular research projects or other inputs; this problem is also referred to as *impact accretion*. The reasons it is so difficult to make attributions is because impact diffuses through time and space, and all research builds on earlier research. Moreover, as research and development becomes more global, it is nearly impossible to make attributions to a particular research project or researcher; this is called the *internationality problem* (Bornmann, 2013; Martin, 2007). A similar challenge is referred to as the *causality problem*: the difficulty with tying impacts to causes (Bornmann, 2013; Martin, 2007). Additionally, the impact of research oftentimes depends on people outside of the research system (e.g., others who make intellectual and financial investments) (Rymer, 2011).

Together, these issues make it difficult to connect the impact of research with a particular research project or researcher.

Difficulties Associated with Assessment and Evaluation of Impact

The difficulties associated with the assessment and evaluation of the societal and context-specific impact of research relates to what should be assessed and how; when the evaluation should take place and who is qualified to conduct it; and unintended consequences of assessment and evaluation.

One of the major issues with assessing impact starts with data. Unlike the data available for measuring the scientific impact of research, there is a lack of data on the societal impact of research (Spaapen & van Drooge, 2011). This is also true for impact that happens within the context of a particular discipline (e.g., engineering education). For ease of reference, I will refer to this as "context-specific impact" throughout the rest of the paper. The place for collecting data on impact is somewhat illusive—where one looks to observe it is not always apparent. Furthermore, the data this is available in dispersed across federal agencies and research institutions, and is not formatted consistently (Lane & Bertuzzi, 2011). Additionally, the current data infrastructure does not allow one to easily track connections between research and societal outcomes and are inadequate for decision-making (Fealing, Lane, Marburger III, & Shipp, 2011; Lane & Bertuzzi, 2011; NSTC, 2008).

As it relates to how impact should be assessed, there are limits on the extent to which the impact of research can be quantified, and quantifying the research outcomes is not easy (Lane, 2009). Linear assessment models assume that the outputs of research are always a codified form of new scientific knowledge; however, this approach ignores knowledge that cannot be codified –for example, tacit knowledge that exists among trained people— but is just as important (Martin, 2007). Martin (2007) justifiably argues that there are "no perfect measures [of impact], only partial and imperfect indicators" (p. 10).

There are two difficulties associated with the timing of assessing impact. The evaluation timescale problem states that the timing of the evaluation will affect the impacts that are observed (Bornmann, 2013; Martin, 2007). This issue is particularly important in context in which stakeholders plan to use the insights from impact research to inform decision-making— because the decisions will be made based on the information available at the time, not on what may happen in the future. Another time-related issue is the temporality problem. This is the time span between research and its embodiment in products, processes or social practices (Lane & Bertuzzi, 2011; Scott et al., 2011; Spaapen & van Drooge, 2011). "The time between the

performance of research and when its benefits become apparent can be significant, unpredictable, and differ for different kinds of research" (Rymer, 2011, p. 3). Some postulate that "it may take years, or even decades, until a particular body of knowledge yields new products or services that affect society" (Bornmann, 2012, p. 673). Rymer (2011) recommends assessing the impact of research in terms of what it aimed to achieve and capable of producing, not based on all the impacts that are possible.

Yet another problem associated with assessing societal impact of research is determining who should conduct the assessments. One logical recommendation is for researchers to conduct assessments of research impact. Researchers, however, tend to have one of two responses to such requests: feelings of disinterest or feelings of inadequacy (Bornmann, 2013; Holbrook & Frodeman, 2011; Spaapen et al., 2007). "Scientists generally dislike impact considerations, which they often see as challenging their authority and undermining the autonomy of the scientific enterprise" (Holbrook & Frodeman, 2011, p. 244). On the other hand, some researchers feel they do not have adequate expertise to evaluate the societal impact of research since such requests are beyond their disciplinary expertise (Holbrook & Frodeman, 2011). Because identifying the appropriate people to conduct assessments of research impact is an important part of studying it, researchers' feelings of disinterest or inadequacy add to the challenges associated with studying this topic.

While there is value in generating ways to assess and measure impact in ways that take the aforementioned difficulties into consideration, there could also be a danger associated with conducting such assessments and evaluations. One potentially negative consequence of measuring the impact of research is that it can distort behavior (Rymer, 2011). Instead of using an improved understanding of impact *to inform* research decisions, researchers may begin to use it *to drive* their research. Researchers may begin to strive for the impact that gets measured, as opposed to conducting research based on guidelines of scientific inquiry (National Research Council, 2002). Again, issues with data, methods, timing, personnel, and unintended consequences add to the difficulty of assessing the impact of research.

Difficulties Associated with Interpretations of Impact

If all stakeholders viewed impact the same way, it would be easier to study the dimensions of research impact. This is not the case, however. There are three difficulties associated with interpretations of impact. The societal impact and context-specific impact of research will vary based on the scientific work, since the research results will affect different aspects of society and the contexts of interest. As a result, there is no one model for assessing research impacts that will fit all research types, disciplines and institutions around the world (Bornmann, 2013; Martin, 2011; Molas-Gallart, Salter, Patel, Scott, & Duran, 2002; Rymer, 2011). Thus, any existing research impact assessments developed for one purpose will need to be modified to be relevant and applicable to another context of interest. In addition to the fact that impact looks different in different contexts, impact can come in different magnitudes: sometimes impact is very large but oftentimes it is very modest (Rymer, 2011). Rarely will all stakeholders agree on the worth of the impact (Rymer, 2011).

There is one final point related to the difficulties associated with studying the societal impact of research. It is easy to assume that impact implies a benefit or advancements.

However, it is important to remember that impact may not always be desirable or positive (Bornmann, 2013; Martin, 2011). Moreover, there may be instances where the same research impact can be interpreted as positive, negative, or neutral—depending on the stakeholder's perspective (Bornmann, 2013; Martin, 2011; Rymer, 2011). Despite all the difficulties associated with studying societal and context-specific impact, there are studies that have begun to address this topic and there are things the engineering education community can do to improve our understanding of research impact, and our ability to communicate it effectively.

Continuing the Impact Conversation in the Field of Engineering Education

While there are many challenges associated with characterizing, communicating and evaluating the impact of research, there are many things the engineering education community can do enhance our understanding of research impact. Such improvements must start with how we conceptualize and talk about research impact.

In light of this, individual members of the engineering education community can use the three dimensions of research impact to inform how they structure the content of any narratives they write in the impact of their research. Again, the three dimensions of research impact can be defined as:

> **Scientific Impact:** Advances in reliable knowledge (i.e. theories, methods, facts, models) that primarily influence academic communities
>
> **Context-specific Impact:** The influence of methods or results of an R&D project on the people, priorities, and/or processes in the context of interest
>
> **Societal Impact:** Research results that influence social, cultural, environmental/natural, or economic capital of a nation

Additionally, members of the community can begin to make efforts to better document connections between research activities and impact. Be open to impacts other than those that are traditionally codified. Shifts like this help with getting better data on the impact of research and to being addressing other issues surrounding connections between research impact and research projects.

Apart from things that individual members of the engineering education community can do, there things we can collectively. One necessary first step is to articulate a nuanced description of what impact looks like in our context. In a paper on frameworks and review articles, Schwarz, Mehta, Johnson, and Chin (2007) define a framework as the "exposition of a set of assumptions, concepts, values, and practices that constitutes a way of understanding the research within a body of knowledge" (p. 41). Over the last ten years, frameworks have been developed to characterize research impact in domains such as health science research (Donovan & Hanney, 2011; Kuruvilla, Mays, Pleasant, & Walt, 2006), arts & humanities research (Levitt et al., 2010), and informal science education (Allen et al., 2008). These frameworks facilitate a shared understanding and language of impact as researchers communicate among themselves and share impact insights with those outside the community. However, within the context of engineering education, there is no shared language for communicating the impact of research. Although the engineering education community is struggling to articulate what the impact means, these are frameworks we can learn from and can serve as a basis for developing something comparable for our field. A framework characterizing the impact of research in engineering education would not only be a way to raise the conversation on impact to a more sophisticated level among engineering education researchers and practitioners, but it will also advance the scholarship on impact that extends beyond this field.

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