Universities Conducting STEM Outreach: A Conceptual Framework

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Abstract

This article addresses the positioning of science, technology, engineering and mathematics (STEM) outreach programs within universities' frameworks. Though universities in many respects form a rather homogenous international community, there is great diversity in regard to the provision of STEM outreach by different institutions. To explain this diversity a conceptual framework was developed by using the Theory of Legitimacy as an organizing concept. The framework considers two opposing scenarios that form a continuum between them, namely: 'top-down' initiative by the university governance, versus *'bottom-up' grass-root initiative. Using the Theory of Legitimacy, internal and external outreach relationships are characterised and explained under the two scenarios. The framework was applied to two exemplary settings, Australia and Israel. The data analysis reveals that the Australian universities' outreach aligns with the bottom-up scenario whereas the Israeli universities align with the top-down scenario. The differences in internal and external legitimacy were found to account for the low performing fragile system in Australia as compared with the high performing, growing system in Israel.*

Key words: STEM outreach; STEM informal education; tertiary education policy; Theory of Legitimacy; public understanding of science; science outreach; science communication.

Universities around the world routinely engage in STEM outreach programs, broadly referred to as 'Informal Education' (NRC, 2009). These programs may take various forms such as providing out-of-school science enrichment to school students, public lectures, on-site and off-site teachers' professional development programs, the direct teaching of students in schools, and many more.

Though universities in many respects form a rather homogenous international community, there seems to be a great diversity in regard to their provision of STEM outreach. For example, a comparison that was made between the outreach programs delivered by the nine universities in the state of Victoria, Australia and the seven universities in Israel revealed an estimated delivery ratio of one program to 47,200 people in Victoria, compared to one program to 5,050 people in Israel (Authors, unpublished project report, Victoria University, 2015). In Israel, as early as 1969, the government formed close collaboration with the universities leading to the establishment of nation-wide outreach programs, partially funded by the government (Knesset Research and Information Centre, 2002). Contrarily, in Australia there is no similar formal governmental recognition of informal education and many outreach programs rely mainly on self-leveraging (Authors, unpublished project report, Victoria University, 2015).

In Europe, Neresini & Bucchi (2011) compared public engagement (PE) across 40 tertiary institutions. They concluded that there is 'significantly unequal PE performances among research institutions in Europe' (p. 77). They also found 'remarkable distance between a few, very active institutions and a majority of scarcely active institutions in terms of public engagement' (p. 77).

From a practical point of view, the high diversity of outreach within the relatively homogenous tertiary structures may also be demonstrated by the fact that while academic

staff routinely move from one university to another, this is not the case with staff affiliated with outreach provision. Rarely an outreach provider at one university may find a similar job in another university.

The observed differences between universities' outreach operations and all other core university businesses are at the basis of the following research question: What conceptual framework may be developed for explaining these differences? Other relevant questions in this context include: What drives the outreach development? How is outreach supported and maintained? What relationships do outreach programs develop internally within their institutions and externally with their stakeholders?

In an attempt to answer some of the above questions, the present article aims to develop a conceptual framework for outreach positioning within universities and to demonstrate it empirically by applying the framework in comparing two locations in Australia and Israel. In developing the framework, the Theory of Legitimacy (Suchman, 1995) is applied to explain various aspects related to policy, management and the internal and external relationships that are formed. When addressing the diversity of programs, two opposing scenarios are considered. The first is a situation in which the university develops a top-down policy and mission statement to disseminate STEM through outreach. At the other extreme is a situation in which the university's governance does not include STEM outreach in its core businesses and does not develop any related policies. These two extremes set the boundaries for the framework which will be discussed and applied ahead.

Literature review

High quality delivery of STEM education is crucial for the continuous growth of post-industrial economies and for increasing the resilience of societies worldwide. Scientifically literate citizens are required in government, industry and communities, all in which STEM-

related policy and decisions are routinely being made (Australian Government, DEST, 2003; ICSU, 2011; NRC, 2012; Tytler, 2007; Tytler & Symington, 2006).

In recent years there has been a growing concern that the goal of 'science education for all' is not being met and education systems are failing to attract students to STEM. The term 'crisis' has recently been used as a cross-sectorial term by governments, industries and educators alike, to describe the diminishing proportion of students in the post-compulsory years who are undertaking science-related studies, particularly in the physical sciences (Australian Government, DEST, 2003; EU, 2004; Jenkins & Nelson, 2005; Masters, 2006; OECD, 2006; Osborne & Collins, 2001; OSTP, 2010; Roy. Soc., 2010; Speering & Rennie, 1996; Tytler, 2007; UNESCO, 2008).

Similar to the crisis within the formal education systems, in the public sphere, science is increasingly being mistrusted and de-legitimized by various groups, in debates such as, for examples, the climate change or, evolution *versus* creationism (Leshner, 2007). Advances in science further contribute to alienation by eliciting fears and doubts witnessed in public responses to genetic engineering and stem cell technology.

In response to these growing concerns, over the past few decades both governmental and research efforts have been directed toward increasing the role of informal education in enhancing citizens' scientific literacy (NRC, 2009; Ziman, 1991). In the United States, the Academic Competitiveness Council has listed informal education as one of three integral pieces of the US education system, alongside K-12 and tertiary education (NRC, 2009). The council stated that informal education is needed to ensure 'U.S. economic competitiveness, particularly the future ability of the nation's education institutions to produce citizens literate in STEM concepts and to produce future scientists, engineers, mathematicians, and technologists' (US Department of Education, 2007, p. 5).

Within this sphere of a growing emphasis on informal education, both universities as institutional initiatives and their academic staff as individuals, have been participating in providing outreach programs in diverse ways. Some examples are provided in what follows.

Examples of outreach programs

Outreach programs may range between small projects, such as an academic developing a program in her or his child's school, all the way to projects run by consortia of universities.

In Australia, the Science and Engineering Challenge is a hands-on, competitive, workshop-based STEM outreach program delivered annually across the country, reaching 15,000 school students per year. The aim of the program is to inspire students to pursue STEM at higher educational levels. The participants are students in Years 9-10. The program runs as a collaboration between the University of Newcastle in New South Wales, Rotary International, local universities, sponsors and local teachers. The challenge is delivered simultaneously at various locations throughout Australia (Husher, 2010, p. 103). Another broad-scale Australian project is called: 'the Australian School Innovation in Science, Technology and Mathematics' (ASISTM). The goal of ASISTM is to advance STEM education by opening up classrooms and creating networks for supporting teachers and students. This governmental initiative provides funding for over 350 projects that involve partnerships between schools and outside agencies such as universities, industries, government departments, and community associations. These external 'teacher associates' bring with them contemporary practice and knowledge in STEM (Tytler, *et al.*, 2011). Outside the school classroom, Australia wide more than 130,000 Australians are active in over 90 Citizen Science projects, predominantly in environmental science fields. Citizen Science networks form relationships between professional scientists and community members in various ways. These include: citizens collecting or processing data for scientists; engagement in work beyond data collection, such as project design, analysis and/or

communication; or, citizens and scientists working together in all aspects of the scientific process (Pecl et al., 2015).

In Israel, the program 'Youth Pursuing Science' (translation from the Hebrew term: 'Noar Shocher Mada') operates in 17 tertiary education and research institutions throughout the country. It provides STEM programs for primary and secondary students through out-of-school clubs, school excursions and incursions, out-of-school research workshops for student groups, and STEM summer camps. The presenters are post-graduate students who receive learning scholarships in return for their contributions. The Weizmann Institute of Science extended this program and developed its own institute for STEM education, the Davidson Institute for Science Education. In 2016 it was reported that the yearly rate of school student participation in the programs is 50,000 (Weizmann Institute of Science internet site). One of the programs run by the institute is called 'Kamatz' (translated as: 'Young Science Groups'). It involves low-achieving middle school students in after-school science and technology activities. The program aims at bridging between the school's formal context and the after-school's informal context, in a way that increases the motivation and self-efficacy of the students, thereby promoting their achievement in the science and technology classrooms (Falik, *et al.*, 2013). 'Mind the Gap' is a program initiated in 2008 by women working in Google-Israel. The aim is to address gender disparity in STEM. The program hosts female secondary school students at Google's offices and sponsors their visits at research and development labs, university classrooms, and conferences. The 2011 assessment revealed that 40 per cent of the participants later chose computer science as a secondary school major (Drori & Netivi, 2013, p. 33). The Ilan Ramon Youth Physics Center was inaugurated in 2007. It offers high-quality physics instruction for excelling teenagers on the campus of Ben-Gurion University of the Negev. It also runs hands-on learning activities in schools in 15

cities across Israel's southern region, reaching some 8,000 school students per year (Drori &
Netivi, 2013, p. 34).

Conceptualizing STEM outreach within universities

The question of how outreach may be framed within universities' policies and operations
appears in the literature from two opposing perspectives. The first perspective is the
moral/philosophical perspective, outlining universities' obligations to the public. The second
examines universities' actual operations within a constraining market environment. These
two approaches create a tension between them. The first, is calling for altruistic engagement
for the benefit of society and the second, is behaviour calling for money-seeking in a
competitive academic environment.

Over the years, there have been many calls for universities to increase their engagement
with their communities. Lerner and Simon (2013) stressed the moral obligation of
universities to make a difference in the lives of Americans and in building communities'
capacities to find solutions to their problems. They call for creating 'Outreach Universities',
universities removed from the 'enclave of ethereal elitism' (p. 379). From this perspective,
universities are required to review their scholarly functions and, service to their communities
needs to become part of the core businesses, alongside knowledge creation, and education.
High profile committees, and reports such as the House of Lords Select Committee on
Science and Technology (2000), the Royal Society and Royal Academy of Engineering
(2004) and the European Charter for Researchers (2005) have also addressed scientists
directly, calling upon them to increase their engagement with the public (Holliman *et. al*.,
2009; Mesure, 2007; Neresini & Bucchi, 2011). Engaging in a dialogue with the public is
perceived as essential for reducing tensions regarding issues of public concern. Leshner
(2007) claims that the role of communicating science cannot be left to a select few, due to the
breadth and intensity of the socio-scientific issues. To this end, academics are increasingly

feeling pressure to communicate their research to the public. Gregory and Miller (1998) described this trend as academics 'being delivered a new commandment from the high: thou shalt communicate' (p. 1).

So far, in some western countries, there is little evidence that governments' support moves beyond rhetoric. A report by the UK National Co-ordinating Centre for Public Engagement found that national policy regarding university-school partnerships is disjointed, lacks coherency and is unsustainable (Greany *et al*., 2014, p. 9).

When moving beyond universities' moral obligations to society, attention needs to be given to fundamental changes that have taken place in universities' positioning within society over the past few decades. These changes are reflective of the New Public Management and the neo-liberal public sector reforms (Hood *et al*., 2004). Derek Bok (2003), in his book 'Universities at the Marketplace' analyses the growth in profit-seeking and commercialization within universities' operations. Universities' operations have become more and more influenced by the need to earn income from teaching, research, and campus activities. Many explanations have been provided for the growing sovereignty of market forces over the higher education system. These include the influences of corporate culture; influences by donators; the reduction in government support to universities in countries such as the USA, Britain, Australia, Scandinavia, and Holland; and, 'attempts to quantify matters within the university that are not truly quantifiable, such as trying to express matters of value in monetary terms rather than qualitatively' (Bok, 2003, p.3). Olsen and Maassen (2007) perceive this movement as 'solutions looking for problems'. The solution is the taken for granted assumption that a more competitive economy, requires 'more determined university … leadership and management capacity that matches those of modern private enterprises' (p. 4). From this perspective, the 'knowledge economy' has been taking precedence over the 'knowledge society' (Olsen and Maassen, 2007, p. 8). Against the backdrop of this changing

scene, the development of a culture of competition between universities is of particular importance for understanding the positioning of outreach programs within universities' operations. In Australia, the direct relation that exists between the number of enrolled students and the universities' incomes encourages universities to compete for students. Though, the overall income is an outcome of a multitude of factors, students' numbers are one of the factors influencing the universities' ability to perform research. This, in turn, spirals down to increased money-seeking activities, such as outreach programs targeted toward student recruitment. Husher (2010) has identified these marketing approaches in Australian outreach programs, noting that when assessment is being performed, it is mostly focused on marketing objectives rather than on the programs' objectives.

Universities' management models

Analysis of universities' management models provides a useful lens for understanding the above dichotomy between outreach as a social service and outreach as a money-seeking activity. Olsen (2005) suggested four visions of university organization and governance, each having its own constitutive logic, criteria for assessment, reasons for autonomy, and causes for change. The four visions are: (i) the university is a self-governing meritocratic community of scholars; (ii) the university is an instrument for national political agendas; (iii) the university is a representative democracy; and, (iv) the university is a service enterprise embedded in competitive markets (p. 8). These four models may be further grouped in accordance to the 'source of autonomy' and in accordance to 'the internal relationships between the actors'. In regard to the source of autonomy, in models (i) and (iii) the university operations and dynamics are governed by internal factors, whereas in models (ii) and (iv), these are governed by environmental factors. In regard to the internal relationships, in models (i) and (ii) the actors have shared norms and objectives, whereas in models (iii) and (iv) these are in conflict (*ibid*, p. 8).

When considering the four models in relation to the social-moral obligation *versus* the market approach described above, it seems that model (i) is aligned well for the social-obligation approach, whereas models (iv) is aligned with the market approach. In model (i) the source of autonomy is internal and there are shared norms and objectives. These conditions could create a favourable environment for the proliferation of outreach as a moral-social service. Contrarily, in model (iv) the source of autonomy is external, beyond the universities' control. In addition, the actors influencing the university's management are in conflict, and competition prevails over cooperation. Under these conditions it may be expected that outreach will be embedded within the universities' marketing efforts.

The division offered by Olsen's (2005) model between shared *versus* conflicting norms and objectives is also a useful lens when considering the outreach programs' legitimacy.

Outreach management

Studies specifically examining how outreach programs are managed by the universities are scarce. The few that exist predominantly report a lack in management structures, with limited communication between the various faculties administering STEM outreach (Krasny, 2005). Outreach programs are not backed by strategic planning across the university (Beck *et al*., 2006; Greany, *et al*., 2014). The predominant operation model is a 'start-stop' model based on funding availability (Greany *et al*., 2014). There are no criteria for assessment or rewards for high performance.

The lack of strategic planning is also manifested in the ways in which programs are initiated and developed. Many of the programs are based on individual relationships formed between particular researchers and community members. When the initiating staff move away, the programs are often halted (Greany *et al*., 2014). Knox (2001) notes that with a few exceptions, universities' faculties do not evaluate the outreach they deliver.

Research so far has provided limited explanations for the above anecdotal evidence pertaining to university-led outreach operations.

The Theory of Legitimacy

The Theory of Legitimacy provides a useful framework for explaining the diverse modes of outreach operations across universities. It explains how services establish themselves by seeking legitimacy. Suchman (1995) offered the following definition: 'Legitimacy is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions' (P. 574). Legitimacy is considered essential for programs' operation since it ensures the flow of resources and creates favourable conditions for performing (Deephouse, 1999). It operates as an 'anchor point addressing the normative and cognitive forces that constrain, construct, and empower organizational actors' (Suchman, 1995, P. 571, in Deephouse and Suchman, 2008).

The processes of legitimation operate at the internal institutional level as well as externally, at the interface between an organization and its society. Internally, add-on services may become established within organizations through a process of aligning their missions and goals with those of the organization, thus gaining legitimacy and securing their operations (Rincon and George-Jackson, 2014). Externally, organizations that have institutionally developed services they wish to provide, aim to secure their long-term existence by aligning their actions and goals with the values and perceptions of society. These implicit social contracts were described in Williamson and Lynch-Wood (2008) as follows: 'Legitimacy between companies and society can be said to require an express or implied social contract (Shocker and Sethi, 1974; Donaldson, 1982) … 'Businesses will undertake socially desirable actions in return for approval of its objectives' (Williamson and Lynch-Wood, 2008, p. 134).

Ashforth and Gibbs (1990) proposed three purposes for legitimation efforts: Gaining, maintaining, or defending legitimacy (in Deephouse and Suchman, 2008, p. 51). Aldrich and Fiol (1994) noted that: 'the highest form of legitimation is achieved when a new product, process, or service is taken for granted.'(in Deephouse and Suchman, 2008, p. 648).

By applying the Theory of Legitimacy as an organizing concept, it becomes possible to develop a framework for understanding the different ways in which outreach is enacted by university institutions and its internal and external relationships with the various stakeholders.

A conceptual framework for university-led STEM outreach

For developing the framework two opposing scenarios are considered as framing the boundaries of outreach operations within universities. The two ends embody a continuum which allows for a range of operational modes in between. At the one end is a scenario in which the university governance develops a top-down policy and management systems for performing STEM outreach programs. At the other end is a scenario in which STEM outreach develops spontaneously as bottom-up initiatives, and no policies are put in place to direct these operations.

The internal and external relationships that are formed in regard to outreach differ significantly under the two scenarios. The internal relationships are those that are formed between the outreach programs and stakeholders within the organization. These include the universities' governing bodies, the outreach coordinators, academics involved, presenters, and administration. The external relationships are those that are formed between the outreach programs and stakeholders outside the university. These include the government, funding bodies, the general public, other formal education systems, and F-12 school students.

Top-Down Scenario

The top-down scenario describes STEM outreach operating under high institutional legitimacy. The programs, their coordinators and staff enjoy internal legitimacy within their

organizations. This scenario is well aligned with Olsen's (2005) university management models (i) and (ii), in which the actors have shared norms and objectives, thus contributing to internal legitimacy across all the institutional levels.

Strong links exist between the outreach programs and other university management structures. A policy would be in place to direct the operations. The university would also establish management and administrative systems backed by appropriate funding to run the programs. Emphasis would be given to professionalism and selection of staff by merit. The coordinators would be held accountable for the performance of outreach. The university would allocate space, time and facilities for the outreach operations. The development of supporting structures ensures that the programs are not dependant on individual initiatives and volunteer work of academics and other staff. Under this scenario, the programs would be stable over time and it is unlikely to find the 'start-stop' mode of operations.

To reinforce high internal legitimacy, the programs would aim to obtain high impact, reaching far and wide to broad audiences, achieving high participation rates, thereby meeting expectations and securing legitimacy. Efforts to increase and diversify participation would shape the programs as follows:

- High internal legitimacy would reinforce the seeking of societal legitimacy by aligning the programs' goals and objectives with the norms and values of the society.

- Approval by the government would be sought by aiming to address the government's priorities. The government's recognition is a key for leveraging further legitimacy by other stakeholders, ensuring ongoing operations and funding.

- All social sectors would be regarded as potential clients, in accordance with society's prioritization. Particular emphasis would be given to school students who are regarded as the prime focus of society's educational efforts.

- Partnerships may be formed with formal education systems and other bodies with shared goals. Unlike the case of the bottom-up scenario in which the programs may channel their operations through the formal education sector, in the top-down scenario the partnerships are based on mutual interests with a focus on addressing society's needs directly.

- The publication of the programs would be open to the public and easily accessed through the internet.

The high internal legitimacy creates expectations for innovation and state-of-the-art practices in STEM outreach, in the same way that this is expected in research. This allows for experimentation with best practices, fine-tuning the programs to accommodate special groups and special needs, and implementing creative approaches to outreach. There is freedom to offer programs that require longitudinal out-of-school and extra-curricular participation. Building on Griffin (1998) and Falk and Dierking (2000), the NRC (2009) report describes these environments as 'typically characterized as learner-motivated, guided by learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open ended' (p. 11). The contribution to the learners was described as: 'learners thrive in environments that acknowledge their needs and experiences' (NRC, 2009; p. 5).

Bottom-Up Scenario

Contrary to the top-down scenario, this scenario involves limited links between the STEM outreach programs and the central university management systems. These programs evolve spontaneously through individual academics' initiatives. Once they are up and running the discrete faculties would attempt to support them within their limited capacity, as add-ons. Often, the programs operate under the university governance's 'radar', unregistered and known only to those who are directly involved with them. In this scenario, the main challenge that the programs face is obtaining legitimacy within the organizations. The bottom-up

scenario aligns with Olsen's (2005) models (iii) and (iv) in which the actors' norms and objectives are in conflict. Such environments hinder internal legitimacy. Striving for legitimacy may become a survival issue impacting on all other aspects of the programs.

One way of obtaining internal legitimacy is by aligning the goals and values of the programs with the university's money-seeking activities. In countries such as Australia, where the universities' incomes depend on student numbers, a claim would be made that outreach supports student recruitment efforts, thus increasing the universities' incomes. The lack of policy implies a lack in central coordination and supporting structures. The supply of space, facilities, administration and other services would be based mostly on good will and availability.

To ensure their ongoing operations, outreach programs are often required to seek different types of legitimacy by the various departments in the same university. University departments may hold different values, norms and objectives. To obtain the departments' legitimacy, the various norms and objectives may be internalized to the extent of developing an assemblage, each tailored to suit those of various parts of the organization.

The lack of legitimacy also results in a lack of consistent, well-structured, long-term planning. The programs are constantly under pressure to generate funding. They are over-dependant on volunteer work by academics and other staff. There are no in-built frameworks for selecting coordinators and presenters. These are selected in accordance with availability and their roles are flexible with frequent changes.

Being placed at the bottom of the 'pecking order' makes them sensitive to organizational pressures. Any change that occurs at the university may have an impact on the programs' running. This includes even minute changes. For example, if the university offers a new course in a given year, this might result in not having an available space for conducting outreach in that year. All these create a 'start-stop' mode of operation. When there are

15

positive enabling conditions the programs would start and when these conditions change, the programs will no longer be offered.

The problems related to obtaining internal legitimacy carry on to impact the external legitimacy of the programs. Similar to the way in which internal legitimacy is sought by internalizing objectives external to the programs, external legitimacy is also likely to be sought by taking a client-perspective approach. The programs that cannot rely on internal support will aim to create reliable partnerships outside the organization by adjusting the programs' objectives and values to those of the prospective partners or clients. As a consequence, the internal inherent objectives of the programs may be compromised. For example, in the Australian universities' context there is a strong tendency to form partnerships with schools, where the schools are perceived as reliable clients. By committing to satisfy the schools' needs, the needs of the students may be compromised (Authors, unpublished project report, Victoria University, 2015). The difference between schools' goals and the students' goals is substantial. While the schools are obligated to carry out the curriculum, students often find it boring and irrelevant (ICSU, 2011; Tytler, 2007; Tytler *et al*., 2011). Such semi-school environments were discussed by the NRC (2009) report as: 'much of science instruction in schools focuses narrowly on received knowledge and simplistic notions of scientific practice' (p. 13).

A fundamental aspect of informal education is students' free choice (Fortus and Vedder-Weiss, 2014). When programs are developed with the aim of supporting schools' curriculum, the teachers decide which outreach program the class will participate in. Students are not free to pursue their own interests. Curriculum limitations also create constraints on the length of the programs. When outreach is developed to support schools' needs, the programs will tend to be based on one-off exposures that are limited in their effectiveness (NRC, 2009). In a study examining Australian science outreach programs, Husher (2010) found that the major

factors influencing the choice of outreach programs managers regarding which content to deliver are the school curriculum and responses to schools' requests. This creates a situation in which most programs are intra-curricular.

In the bottom-up outreach scenario the scope, diversity, and types of programs offered would be limited due the lack of legitimacy required for upscaling. In regard to publicity, due to the client-based approach, notification of programs would be limited to a pre-selected list of schools rather than open to the public, thus limiting accessibility and possibly social equity.

Table 1 summarises the main characteristics of the two opposing scenarios, the top-down and the bottom-up models of STEM outreach.

TABLE 1

STEM outreach internal and external relationships within the top-down and bottom up models

Examination of Table 1 reveals that when the university governance is the legitimizing body, as in the top-down scenario, there is a good alignment between the internal and the external claims for legitimacy. This is not the case in the bottom-up scenario. This lack of consistency translates into lack of coherence in goals that then seems to permeate and influence all other operations of the outreach in negative ways.

Applying the conceptual framework

To apply the conceptual framework, two sites were chosen for comparison, Australia and Israel. The two sites were chosen on the basis of previous research pointing out the vast differences in the scope of STEM outreach in the two settings (Authors, unpublished project report, Victoria University, 2015). It is important to note that the data presented in what follows serves mainly as an indicative example of the application of the model, and as an

invitation for further research. As such, any rigorous methodology for applying and comparing the data across the two settings is beyond the scope of this conceptual article.

The developed characteristics of STEM outreach positioning across the two scenarios of the framework (see Table 1) cannot be applied directly to compare data across the top-down and bottom-up scenarios. The process of application involves an intermediate stage of developing a set of measurements in the form of performance indicators (PIs). These PIs may then be applied to compare data obtained from the two sites.

Developing performance indicators

A set of measurable performance indicators were designed to reflect and represent the main characteristics of the conceptual framework, as they appear in Table 1. Indicators provide a measurement for assessing the qualitative or quantitative performance of a system (Cave, 2006). The Organisation for Economic Co-operation and Development (OECD) defined an indicator as a 'numerical value used to measure something which is difficult to quantify' (Cuenin 1986, p. 6). The PIs differ from simple indicators in that 'they imply a point of reference. For example, a standard, an objective, an assessment or a comparator and therefore relative rather than absolute in character' (Cave, 2006, p. 22). For an indicator to become a PI, a value judgment needs to be involved. In this regard, PI 'reduce the complexity of subjective judgements to a single objective measurement' (Laurillard, 1980, p.187).

The developed PIs were designed to address the following criteria: (i) The required data may be retrieved easily from publicly available information; and (ii) they are reflective of and cover most of the scope of the model's characteristics in a reasonable and trustworthy way. The following PIs were developed: Government participation in funding; central management; secured funding; program's stability over time; number of programs; diversity of programs; the length of student participation required by the programs; relation to school

and to curriculum; distribution by school level; and, public accessibility to information regarding the programs.

Applying the indicators

Two publicly accessible data sources were chosen to compare the Australian and Israeli university-led STEM outreach programs.

In Australia, two sources of data were used:

- *Data source 1*. The main data source used was a publication by the Office of the Chief Scientist (2016), entitled 'SPI2016. STEM programme index 2016'. The publication lists all the university-led STEM outreach programs known to the government.

- *Data source 2*. As a secondary source, we draw on an unpublished project report entitled 'Evaluating university-led STEM outreach'. The study was carried out in 2015 by a team of Victoria University researchers. Data were collected from the nine universities in the state of Victoria, Australia.

In Israel, there is no equivalent document. Instead, the information was manually collected from three universities' internet sites: the Tecnion- Israel Institute of Technology, located at the northern part of Israel; Tel-Aviv University, located at the centre, in Tel-Aviv; and, the Weizmann Institute of Science, located south of the centre. In Israel there are altogether seven universities and one newly formed university. The university system is highly homogenous and therefore the three selected universities may be regarded as being representative of the system. The decision to choose three universities only out of the seven is derived from the need to keep the data collection manageable and suitable for the purpose of serving as an illustrative example. Some information that could not be obtained from the three sites was collected from government publications.

Table 2 presents the summary of the data collected for the two sites. The table lists for each PI the expected performance at top-down (TD) scenario and at bottom-up (BU) scenario. For each of the sites, Australia and Israel, the findings relevant to the PIs and the evidences are presented. For providing a birds-eye view of the two sites, for each finding it is stated whether it fits into the TD or BU scenarios.

TABLE 2

Applying and comparing the conceptual framework across two scenarios by, PI, expected performance for each scenario, findings and evidences for Australia and for Israel[1]

Table 2 provides an example for the distinctive ways in which STEM outreach may be developed and implemented under the two extreme scenarios of top-down *versus* bottom-up.

The Israeli university system is well aligned with the top-down scenario. Its STEM outreach is operating in a low-conflict environment with high internal legitimacy. This creates a thriving innovative STEM outreach, continuously expanding. In this system STEM outreach enjoys a similar level of internal legitimacy to that of scientific research and similarly, it aims for top performance and state-of-the-art STEM outreach delivery. Externally, the level of social legitimacy is compatible with the 'taken-for-grantedness', which was described by Aldrich and Fiol (1994) as the highest form of legitimacy.

The Australian landscape of outreach is quite different. While in Israel three universities produce approximately 593 programs, in Australia, 45 universities produce approximately 96 programs. The system is aligned with the bottom-up scenario. The

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[1] For each set of evidence, data source (DS) is indicated according to the following Index:
Australian data
- DS1 - Office of the Chief Scientist (2016), 'SPI2016. STEM programme index 2016'.
- DS2 - Unpublished project report, Victoria University, 2015.
Israeli data
- DS3 - Technion- Israel Institute of Technology Internet site.
- DS4 - Tel-Aviv University Internet site.
- DS5 - Weizmann Institute of Science Internet site.

programs seem to operate in an environment of high conflict and very low internal legitimacy. In their efforts to obtain internal legitimacy the programs focus their offerings on secondary students as a recruitment exercise in the service of the universities' marketing efforts. These secondary students are at the point of decision regarding their tertiary education, thus forming a strategic priority, with a ratio of 23:1 secondary to primary programs.

In the lack of internal legitimacy, the programs seek external legitimacy by partnering with stable partners, which are mainly schools. The cost of this form of partnership is the loss of their independence, the need to satisfy the clients' objectives rather than addressing their own goals, and compromising students' needs in favour of satisfying schools' needs. This, in turn, creates a low diversity of offerings, mostly in relation to school curricula and short-term student participation, mainly one-off sessions.

Discussion

The present article addressed the question of high diversity among university-led STEM outreach provision. It asks: What explanation might be provided for the fact that while, universities around the world are increasingly homogenous in their research and teaching they are highly diverse in their approaches to outreach?

The article proposes a conceptual framework to explain the differences. The framework was further applied for comparing two university systems in two countries, Australia and Israel. The framework relies on two main assumptions. The first is the identification of the university's governance approach to implementing STEM outreach as the most important factor affecting diversity. This may give rise to diverse possibilities within a continuum ranging between top-down to bottom-up scenarios. The second assumption is that once the governance position in regard to outreach is identified, all the other characteristics outlined in

Table 1 can then be explained and unfolded by using the organizing concept of the Theory of Legitimacy.

The concept of legitimacy plays a critical role not only in explaining the diversity of outreach, but also in explaining the fundamental difference between the relatively homogenous positioning of research and teaching among universities, as compared to the heterogeneous positioning of outreach. Whereas research enjoys high internal legitimacy across all management models, this is not the case for outreach. The developed framework shows that the level and type of internal legitimacy has high impact on all aspect of the programs' development. This, in turn, impacts external legitimation processes and the types of outreach that is offered. By examining the relationships between the management model (in this case top-down versus bottom – up) and internal and external legitimation processes, it becomes possible to explain both the differences between outreach positioning in universities and other university businesses, as well as the diversity between outreach offerings by universities around the world.

Further research is required to develop a data-base regarding outreach delivery in different countries and an in-depth understanding regarding the ways in which legitimation directs the programs' development under different management scenarios. By applying the framework to broad-based data it might be possible to develop an outreach management model based on best practices. Further, more research is required to examine the relationships between the conceptual framework and other existing university management models, for example in relation to Olsen's (2005) four university visions.

Outreach in STEM is a matter of priority for societies worldwide. Though in recent years increasing attention has been given to the role of informal education in providing an alternative pathway to enhance students' engagement in STEM education, no equivalent attention has been given to universities' contribution toward this end (Australian

Government, DEST, 2003; ICSU, 2011; NRC, 2012; Symington & Tytler, 2005). The present article takes a first step in this direction by providing a framework for evaluating STEM outreach positioning within universities. In addition, by providing examples for the distinct differences that may be found in outreach provision, a case has been made for further research in this area regarding the impact of the programs and how these differences impact on society. Overall, universities contribution to enhancing STEM literacy and recruitment of students to STEM is yet mostly unknown, thus calling for further investigations.

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