This is an Accepted Manuscript of an article published by Springer in JOURNAL OF SCIENCE EDUCATION AND TECHNOLOGY on [14th May 2020], available online: https://link.springer.com/article/10.1007%2Fs10956-020-09834-8

An investigation of university students and professionals' Professional STEM Identity Status

Regina Kelly[1], Oliver Mc Garr[1], Keelin Leahy[1] and Merrilyn Goos[2]

School of Education, University of Limerick, Ireland [1]

EPISTEM, School of Education, University of Limerick, Ireland[2]

Abstract
Set amidst the backdrop of concerns related to entry of students to Science, Technology, Engineering, and Mathematics (STEM) careers, this study seeks to understand the Professional STEM Identity Status of STEM undergraduate students and STEM Professionals. This study utilizes a cross sectional research design to compare participant scores in the categories of Affirmation, In-depth exploration, Practices, Commitment, and Reconsideration of commitment in the Professional Identity Status Questionnaire (PISQ-5d). Cluster analysis was performed on the scores to indicate five Professional STEM Identity Status: Achievement Status, Foreclosure Status, Moratorium Status, Searching Moratorium Status and Diffused Status. We initially envisaged that those in STEM careers would have more established STEM identities reflected in higher numbers in an Achievement Status category, however, this was not the case. These findings raise questions about the dominant approaches used in career guidance for STEM. We conclude that a more fluid and less fixed understanding of Professional STEM Identity may better guide research in the area of STEM and inform institutions that encourage strong affinities to particular STEM careers.

Key Words: STEM Identity, Professional Identity, STEM careers, Higher Education, STEM, Gender

Word count: 5970 (excluding references)

Introduction

An objective of STEM education is to prepare students for a future career and develop their professional identity (Nadelson 2017; Kaufman & Feldman 2004; National Research Council 1999). However, there is a lack of understanding about whether a strong stable Professional STEM Identity exists in those engaged with STEM careers. Approaches to measuring professional identity are reported in Health and Social Care literature (Crossley and Vivekananda-Schmidt 2009; Emerson 2010) and Teacher Education literature (Quirke 2018; Pillen et al. 2013; Cheung 2008) but few studies have focused on Professional STEM Identity measurement (Nadelson et al. 2017). Most of the research in this field is aimed at methods to develop Professional STEM Identity (Nadelson and Fannigan 2014; Kier 2013; Nadelson et al. 2017). Decades of initiatives globally (Gender Gap in Science Database, 2020) have been designed with the intention of recruiting females into STEM career pathways (Kanny et al. 2014). Many of these outreach initiatives promote very specific pillars of STEM, directing these students to choose a particular STEM career and commit to a particular STEM identity. Do STEM undergraduate students or STEM professionals have stable Professional STEM identities? We analyzed undergraduate students and STEM professionals' Professional STEM Identity Status and investigated whether a stable STEM identity was evident, with the aim of understanding if attempts to develop Professional STEM Identity Status are justified when recruiting people into STEM careers.

This study examines identity from a psychological perspective and specifically draws on the work of Erikson (1968) and Marcia (1966; 1980; 1994). From this perspective, it is argued thatbefore committing to a particular identity, adolescence can be a time of identity exploration.

If this is the case, adolescence is a crucial period whereone's exploration and commitment to a STEM career and identity is an important issue.

This study was guided by two main research questions; How evident is Professional STEM Identity amongst STEM professionals? How, if any, does Professional STEM Identity differ from third-level students studying STEM programmes? With these questions in mind, this paper aims to identify the professional identities of both undergraduate STEM students and STEM Professionals through profiling their Professional STEM Identities. Then the study aimed to investigate if there were any differences in the groups surveyed before discussing the implications for STEM education. The key contribution of this work is to provide evidence regarding the existence of Professional STEM Identity Status in those pursuing a career in STEM in early adulthood and those who are practicing STEM professionals.

Theoretical Framework: identity

Although the term identity as a concept of psychosocial development was first introduced in the 1940's (Erickson 1968) it is still considered a complex concept to define. There are many dimensions through which one can view identity. For example, it can be seen as a fixed or fluid, singular or multidimensional, individual or social, something we 'are' or something we 'do'. Gee (2000 p.99) emphasizes the situational nature of identity, '*being recognized as a certain kind of person in a given context'* and proposed interconnected aspects of identity. As there are many different views of identity and it is beyond the scope of this paper to unpack them, this paper takes from the onset that identity is a contested concept with many different theoretical perspectives. For the purposes of this study we explored identity, and specifically identity formation, through the lens of Marcia's (1966; 1980; 1994) work. We aim to capture the extent

to which an individual begins to associate and commit to being associated with a particular career or profession. With this in mind the following section outlines the basis of this theoretical perspective.

Erikson's (1959) theory of psychosocial development is considered one of the foundational theories of psychosocial development and has had a significant influence in the field of psychology since its development. This theory consists of eight stages that occur throughout a person life. An individual experiences a psychosocial crisis during each stage, which influences their personality development. Erikson (1963) terms these crises as psychosocial as they include the psychological desires of the individual in respect to the requirements of the society they are part of. A strength of this model is the idea that personal growth extends beyond the earlier years. The fifth stage of Erikson's model (identity vs role confusion), viewed as particularly important by him, has had a significant influence on how career guidance of adolescents is approached. This stage is described as a time of exploration with the aim of achieving an identity. Adolescence, according to Erikson, could be seen as a period of psychosocial moratorium where people postpone making choices while they work out their identities. Career guidance initiatives frequently focus on helping students to identify a career to satisfy this quest for identity during this moratorium. However, this focus on achieving an identity (and an associated career choice that one is satisfied with) over-emphasises the importance of adolescence as a period in which identity is achieved. It also downplays the view of identity as an active ongoing identity project engaged throughout one's lifespan. In addition, focusing on choosing a career at this time, when perhaps one does not feel adequately prepared to make such a decision, can have negative and unintended consequences. The work of Marcia

(1966; 1980; 1994) examined this issue further and led to the development of the 'identity status model'.

Marcia's (1966) identity status model extended the work of Erikson's original model, focusing specifically on adolescent identity formation and the extent to which an individual has explored and committed to an identity. This paradigm centers around four statuses each concerning the absence or presence of *exploration* and *commitment*. Identity diffusion is when an individual has not explored or committed to an identity. Identity Foreclosure is where a person has not explored but has committed to an identity. Identity moratorium is where a person is exploring but has not committed to an identity. Identity achievement is where a person has explored and committed to a particular identity. These four status are outlined in figure 1.

Fig 1. Visual representation of the Identity status model (Marcia, 1966; 1980)

Building on Marcia's original model, Crocetti and colleagues (Crocetti et al. 2008; Crocetti et al. 2014; Crocetti et al. 2013) proposed an addition to the two factor model of *commitment* and *exploration* to include *reconsideration of commitment*. In this model, they defined commitment as the choice an individual has made and their self-confidence they develop from these choices. *Exploration* refers to the level to which individuals contemplate their commitment, and their pursuit of information. *Reconsideration of commitment* represents the likelihood of a person altering their existing commitment which reflects a more fluid understanding of identity as an ongoing project (Peticca-Harris and McKenna 2013; Gee 2000). The addition of a third factor required the addition of another identity status, searching moratorium. In this status, a person is defined as having high scores on *commitment* and *exploration* but low scores on *reconsideration of commitment.* Mancini et al (2015) extended Crocetti's model (2008) to include *affirmation*

and *practices*. *Affirmation* refers to the value an individual places on being part of the profession and is positively related to *commitment*. *Practices* represents the behaviors a person may exhibit when engaging in a career (Mancini, et al. 2015). It is positively related to *In-depth exploration* but is a behavior rather than a cognitive measure.

Notwithstanding some of the limitations of this perspective on identity, this perspective offers an opportunity to explore perceived identification with different professions/careers and hence is a good theoretical model to use to examine Professional STEM Identity. However before examining this, the issue of professional identity will be briefly explored.

Professional STEM Identity

There is a significant focus on identity since the mid-20th century, and this research has explored professional identity as well as STEM identity. Students in higher education are on a trajectory to a particular career. Professional identity is linked to their affinity to this profession. Mancini et al. (2015, p.141) describe professional identity as '*ones identification with the groups and social categories to which one belongs by virtues of one's job'*. Prior research has applied Marcia's theoretical framework to evaluate professional identities. Crocetti and authors (2014) concluded from their research on employees' identity statuses that individuals classified in the high commitment status of achievement and foreclosure displayed higher job satisfaction, lower burnout and engaged with more voluntary commitments within a company. Perez, Cromley and Kaplan (2014) reported STEM undergraduate students who engaged with self-exploration before they committed to a STEM career perceived themselves to be more proficient in their STEM major, held their STEM major in higher esteem and believed the effort required of their

STEM major was justifiable. Similarly, Mancini et al (2015) report that achievement and foreclosure identities were most related to superior academic outcomes for undergraduate students. On the contrary, those categorized as uncommitted, searching moratorium, moratorium, and diffusion, exhibited burnout, were negative about their future work, and had higher levels of depression and anxiety.

In the realm of education systems, there is little consensus regarding the meaning of STEM as a construct (Breiner et al. 2012; Pitt 2009). At one level STEM can be viewed as pursuing any of the individual pillars of science, engineering, technology and mathematics; alternatively it can be viewed as a more porous idea consolidating these once separate spheres (Author, 2017). Moving specifically to the issue of STEM identity, few conceptual frameworks are present in the literature (Carlone and Johnson 2007; Herrera et. al 2012). Science identity is recognized as an important factor in students choosing to study STEM and persisting in STEM careers (Carlone and Johnson 2007, Authors, 2019). Carlone and Johnson (2007) define science identity using the interlinking categories of competence, performance, and recognition. An individual identifies as a scientist if they believe they are competent at their subject. This competence is evident in their performance and their performance is recognized by the science community. More recently, Herrera and colleagues (2012) developed on Carlone and Johnson (2007) identity construct across STEM disciplines through the development of a STEM Identity Model. The STEM Identity Model consist of three societal contexts, non-STEM contexts, and STEM contexts.

While these constructs provide information about significant sources of influence on an individual's STEM identify formation, they lack consideration of the flux of an individual STEM identity as they navigate from student to professional level.

As this brief literature review has highlighted, concerns have been raised about students' attraction to STEM-related careers for a number of years. To address these concerns researchers have drawn on instruments from the psychological arena, such as the identity statuses questionnaire, to explore students' commitment to particular careers. Within the theoretical grounding of this study, one of four main outcomes is expected. In an ideal situation, both students and STEM professionals would possess strong achieved Professional STEM Identities, thus providing a strong rationale to promote Professional STEM Identity development. If it is found that students have diffused Professional STEM Identities and professionals have achieved Professional STEM Identities, this indicates the need to increase efforts to develop student identities. If it is found that students have achieved Professional STEM Identity and professionals do not, this indicates that people who choose a career in STEM have strong identities but when they enter the workforce this changes. If both students and STEM professionals have diffused Professional STEM Identities, the emphasis on the development of Professional STEM Identity may be flawed. This study aims to extend this research scope to explore its application in the STEM arena. The following section outlines the research design of the study.

Methodology

In order to explore the Professional STEM Identity statuses of both students and practicing professionals, this study administered the Professional STEM Identity Status questionnaire to a sample of two cohorts. This research was approved by the university's research ethics committee. Employing a cross sectional research design, primary data was collected from the two cohort to compare the Professional STEM Identity Status of each group (Coolican 2017). It

was envisaged that these groups would be distinguishable due to their different stages of their professional level. Participants from each cohort were recruited via email to participate in the study. The researchers invited undergraduate students from a regional university in the west of Ireland, who were studying STEM courses to participate in the study. The sample included 121 undergraduate students. A total of 70 females, 49 males and 2 students who preferred to remain gender neutral. The sample consisted of students from Science (78), Technology (6), Engineering (6), Mathematics (28) and Unknown (3). The researchers invited employees who worked in a STEM industry to participate. The sample included 58 STEM professionals. A total of 43 females and 15 males. The sample consisted of students from Science (33), Technology (3), Engineering (21), and Unknown (1).

Questionnaire

Professional Identity Status Questionnaire (PISQ-5d)

The Professional Identity Status Questionnaire (PISQ-5d) is a tool used to measure professional identity construction processes in university students. The PISQ-5d was developed and validated by Mancini et al (2015). It includes twenty items that evaluate the professional identity of undergraduate students using five categories. There are four items to assess each of the five categories of *Affirmation, In-depth exploration, Practices, Commitment,* and *Reconsideration of commitment*. The test was originally designed to measure psychologists' professional identity construction, however for this study the questions were altered to measure future STEM Professional Identity. This was carried out by replacing the word physiologist with STEM professional. Participants were asked to state the STEM profession they identified with at the beginning of the questionnaire and instructed that wherever the term STEM professional was used they could refer to their stated STEM profession.

Table 1: *Professional Identity Status Questionnaire (PISQ-5d)*

Professional STEM Identity Survey Items and related Categories
Affirmation 1. How important is it for you to become a STEM Professional? 4. How do you feel at this moment in time as a future STEM Professional? 7. Are you looking forward to becoming a STEM Professional? 11. Are you proud of becoming a STEM Professional? *In-depth exploration* 2. To what extent is becoming a STEM Professional a concern for you? 15. Do you ever think about the advantages and disadvantages associated with becoming a STEM Professional? 17. Do you pay attention to what other people think or say about STEM Professionals? 19. Do you ever wonder whether the profession of STEM you choose is the most suitable for you? *Practices* 6. Do you ever read books and / or articles written by STEM Professionals? 9. Do you ever seek information about the different job options that a degree in STEM may offer? 13. Do you ever seek information about the regulations of the STEM practice? (requirements for practicing this profession in your country, etc.) 20. Do you ever participate in meetings and /or conferences where STEM Professionals speak? *Identification with commitment* 5. Does thinking of yourself as a STEM Professional help you to understand who you are? 10. Does thinking of yourself as a STEM Professional make you feel secure in your life? 14. Does thinking of yourself as a STEM Professional make you feel self-confident? 18. Does thinking of yourself as a STEM Professional make you feel confident about the future? *Reconsideration of commitment* 3. If you could change your choice of becoming a STEM Professional, would you do it? 8. Do you ever think that choosing a different profession would make your life more interesting? 12. Do you ever think that it would be better to prepare yourself for another profession? 16. Are you considering the possibility of changing your major in order to be able to practice another profession in the future?

Identification with particular STEM groupings

Research conducted by Park and colleagues (2018) highlight the importance of Professional Identity of STEM students through participating in various social groups. Carrino and Gerace (2016) define STEM professional/science identity qualitatively as self-identifying as a member of a STEM profession, a STEM professional, or as a STEM major. To investigate if a relationship exists between participants' Professional STEM Identity Status and their identification with STEM groups, participants were asked to complete two open questions, (i) what groups are you part of (ii) What groups do you aspire to be part of in the future? The purpose of this question was to investigate if participants identified with STEM social groups or had aspirations of being part of a STEM group in the future. Buczynski, (1991) noted that people who had a stronger identify in a particular area are more comfortable interacting with peers and professionals in their area than those who have lower levels of identity.

Analysis

The Professional Identity Status Questionnaire (PISQ-5d) Likert data was entered into SPSS; 1 represented 'not at all' and 5 represented 'very much'. The means of each item in the categories of *Affirmation, In-depth exploration, Practices, Commitment,* and *Reconsideration of commitment* were aggregated, then standardized. Cluster analysis was performed to classify participants to ensure their scores in each category of the PISQ-5d were similar in each cluster (Scott and Knott 1974). This enabled the researcher to identity participants with similar Professional STEM Identity Status. Participants were clustered into groups based on their scores on each category. A two-step cluster analysis was used, resulting in a cluster solution. The two cluster method was chosen as it is suitable for scale and ordinal data. First it runs pre clustering,

then it runs hierarchical methods to calculate the distance between individuals and then link the clusters.

A Mann-Whitney U test was conducted to compare the differences between the professional and student groups and male and female groups on each of the categories of *Affirmation, In-depth exploration, Practices, Commitment,* and *Reconsideration of commitment*. In instances where there were more than two independent groups a Kruskal–Wallis test by ranks was used.

Open questions were reviewed and coded using an inductive, grounded theory approach. An inductive approach rather than a deductive approach was used as the participant responses were used to generate codes, interconnecting the themes (Creswell & Plano Clark 2007). For example, for the question, 'what groups are you part of? On reviewing the responses it was decided that a STEM group could represent a STEM course groups, career groups and/or professional societies. Decision making regarding how to code the responses was uncomplicated as all responses were easily identified under these categories. For example, a student who answered that they were part of Engineers Ireland were coded as being part of a professional society. The emerging groups aligned with Carrino and Gerace (2016) categories of STEM Professional/science Identity. Frequency counts were conducted to indicate the number of occurrences of STEM groups. Representative quotes were selected to highlight a participant's reasoning. The following section aims to outline the findings. The first section compares the students' and professionals' Professional Identity Statuses. Following this, the second section explores Professional Identity Statuses in gender groups and STEM discipline groups.

Results

The cluster solution (Table 2) displayed little variation to the five status identity dimensions identified by Mancini et al. (2015) and the three-status model of Crocetti et al. (2008).

1. Students with achievement identity status scored high on *Affirmation, In-depth exploration, Practices, Commitment,* and low on *Reconsideration of commitment*.

2. Students in the foreclosure status scored low on *In-depth exploration, Practices, Reconsideration of commitment* and high on *Affirmation* and *Commitment*.

3. Students in the moratorium status scored low on *Affirmation, Commitment, In-depth exploration* and *Practice* and high on *Reconsideration of commitment*. This is the cluster that differed from Mancini (2015) as in their cluster participants scored medium on exploration.

4. Students with searching moratorium identity status scored high on *Affirmation, In-depth exploration, Practices, Commitment* and *Reconsideration of commitment*.

5. Students with diffused identities scored low on *Affirmation, In-depth exploration, Practices, Commitment* and *Reconsideration of commitment*.

Table 2: *Mean values of the five status identity dimensions (n* = 174)

Label	**Foreclosure**	**Diffusion**	**Searching Moratorium**	**Achievement**	**Moratorium**
AFFIRMATION	0.69	-0.77	0.14	0.72	-1.91
RECONSIDERATION	-0.55	-0.25	1.18	-0.67	0.97
COMMITMENT	0.24	-0.46	0.04	0.89	-1.44
PRACTICES	-0.3	-0.9	0.59	0.84	-0.08
EXPLORATION	-0.49	-0.57	0.79	0.75	-0.44

Professional and Student Professional Identity Status

The range of student and professional identities are displayed in figure 2. In total, 18 % of students and 22% of professionals had achievement status and 20% of students and 22% of professionals had diffused identity status. The majority of students (29%) and professionals (28%) were categorized as having foreclosed identities. In total, 20% of professionals and students had searching moratorium identities, 13% of students and 7% of professionals had moratorium identities.

Fig 2: Fig 2: Comparison of Professional (n = 53) and Student (n = 120) Identity Status

A Mann-Whitney U test was used to compare differences between professional and student scores on the categories of *Affirmation, In-depth exploration, Practices, Commitment,* and *Reconsideration of commitment*. From this data, it was concluded that the professional group scored statistically significantly higher than the student group in the categories of *Affirmation* (U = 1968.500, p = 0.000) *Practices* (U = 2502.500, p = 0.016) and *Commitment* (U = 2626.500, p = 0.045).

A Mann-Whitney U test was performed to indicate if there was any difference between participants who choose their college course as their first choice of study or those where it was not their first choice. There was no statistical difference between these participants scores in the categories of *Affirmation* (U = 1575.000, p = .447), *In-depth exploration* (U = 1575.000, p = .447), *Practices* (U = 1618.000, p = .601), *Commitment* (U = 1435.000, p = .130), and *Reconsideration of Commitment* (U = 1451.000, p = .151).

Male and Female Identities

The spread of male and female student identities are displayed in figure 3. The greatest difference between males and females was in the achievement identity status with more females (21%) than males (14%) in this category. Approximately 18 % of male students and 21% of female students had diffused identity status, 22% of males and 19% of females were categorized as searching moratorium, 14% of males and 10% of females were categorized in the moratorium status and 31% of males and 29% of females were categorized as having foreclosed identities.

Fig 3: Comparison of Male (n = 49) and Female (n=70) Student Identity Status

A Mann-Whitney U test was performed to indicate if there was any difference between male and female scores on the five identity categories. There was no statistically significant difference between male and female scores in the categories of *Affirmation, Exploration, Practices, Commitment* and *Reconsideration of Commitment.*

The spread of male and female professional identities are displayed in figure 4. The greatest difference between males and female professionals was in the moratorium identity status with more males (21%) than females (3%) categorized in this category. Fewer male (14 %) than female (25%) professionals had achievement identity status. More females (25%) had diffused identity status than males (14%). Approximately 29% of males and 18% of females were categorized as searching moratorium, 21% of males and 30% of females were categorized as having foreclosed identities.

Fig 4: Comparison of Male (n= 14) and Female (n= 40) Professional Identity Status

STEM Disciplines and Identities

Student identities by STEM discipline are displayed in figure 5. A Kruskal-Wallis H test showed no statistically significant difference in the four STEM groups (student scores) on *Affirmation, Practices, Commitment and Reconsideration of Commitment*. There was a statistically significant difference in the *In-depth exploration* category between the four STEM groups, $\chi 2(2) = 10.616$, $p = 0.014$ with a mean rank of 66.57 for Science students, 55.67 for Technology students, 44.77 for Mathematics students and 40.17 for Engineering students.

Fig 5: Student Identities (n =120) by STEM Discipline

Professional identities by STEM discipline are displayed in figure 6. A Kruskal-Wallis H test showed that there was no statistically significant difference in the three disciplines of STE professional scores in the *Affirmation, Practices, In-depth exploration* and *Commitment* categories. There was a statistically significant difference in *Reconsideration of Commitment* between the three stem groups, $\chi 2\ (2) = 7.463$, $p = 0.024$ with a mean rank of 13.00 for Technologists, 26.14 for Scientists and 35.79 for Engineers. A limitation of this finding is that the sample of Technologists was very small.

Fig 6: Professional Identities (n=53) by STEM Discipline

Identification with particular STEM groupings and Professional Identity Status

To identify the relationship between participants' professional identity and a STEM group, respondents were asked the open question '*What groups are you part of (academically, socially)?*' It was hypothesized that a greater number of participants in the achievement status would list STEM groups. Examples of STEM groups were class groups (e.g. socialize with students in their course), STEM societies (e.g. Science Society), and professional bodies (e.g. Biopharmachemical Ireland). In decreasing order, the findings to this question were.

- Achievement Status: Out of 26 participants in this category, 21 participants listed a STEM group they are part of.
- Diffusion Status: Out of 21 participants who answered this question, 12 participants listed a type of STEM group, whether this was associated with their course or career.
- Foreclosed Status: Out of the 35 participants who responded, 17 listed a STEM group they are part of.
- Moratorium: Out of the 13 participants who responded, 7 listed a future STEM group they would like to be part of.
- Searching moratorium: Out of the 17 participants who responded, 6 listed a future STEM group are part of.

To investigate participants aspirations regarding the groups they would like to be part of in the future, respondents were asked *'What groups do you aspire to be part of in in the future? (career, personal life, family life etc.)'*. Similar to the previous question, this was an open-ended question and any references to career groups and societies were deemed to indicate the

participate wiliness to engage with STEM in the future. In decreasing order, the findings to this question were:

- Achievement Status: Out of the 22 participants that responded, 15 listed a future STEM group they would like to be part of.
- Foreclosed Status: Out of the 31 participants that responded, 19 listed a future STEM group they would like to be part of.
- Diffusion Status: Out of the 11 that answered, 6 listed STEM groups.
- Moratorium: Out of the 8 participants that responded, 4 listed a future STEM group they would like to be part of. 5 participants left this blank.
- Searching moratorium: Out of the 17 participants that responded, 5 listed a future STEM group they would like to be part of.

Summary of main findings

- Professionals and students had similar Professional STEM Identity Statuses. There were low numbers of both groups with achieved status.
- Male and female students had similar Professional STEM Identity Statuses. The greatest difference was the higher number of females in achieved status.
- Professional male and females Professional STEM Identity Statuses differed. More males than females were categorized in the moratorium and searching moratorium identity status. More females had achievement identity status and diffused identity status.

- There was a statistically significant difference in the specific STEM discipline student groups in the category of *In-depth exploration.* Science students had the highest mean rank scores, followed by Technology students, Mathematics students and Engineering students.
- There was a statistically significant difference in the specific STEM discipline professional groups in the category of reconsideration of commitment. Professionals who identified as Technologist scored the lowest, then Scientists, then Engineers.
- The highest number of participants who stated they were part of a STEM group were in the in the achievement status.
- The highest number of participants who stated a STEM group they aspire to be part of in the future were in the achievement status.

Discussion and Implications

In planning this research we initially envisaged that those in STEM careers would have more established STEM identities reflected in higher numbers in an achieved status category, however, this was not the case. Instead, there was no statistical difference between the students and professionals surveyed and further still, low numbers of respondents in each group were recorded as 'achieved status'. This raises a number of questions. Firstly, whether the instrument has the capacity to test for this construct in the first place. It may well be that the idea of a Professional STEM identitiy(and Science, Technology, Engineering and Mathematics identities for that matter) is quite a porous concept in the age of a portfolio career where the merging of Engineering, Science, Technology and Business makes it difficult to differentiate roles and disciplines that reflect more traditional demarcations of professional practice. In that context,

within a shifting STEM landscape in industry, and the erosion of the traditional subject boundaries, it is unlikely that a strong stable Professional STEM identity would exist. This may explain the low levels of *achieved identity* within the industry group and the higher than expected *moratorium* and *searching* statuses.

An alternative explanation for these similar statuses across both students and professionals may reflect more contemporary understandings of identity as being a continuing on-going process (Jones & McEwen 2000). Seen through this light, where less credence is given to early adulthood as a particular period of crises, these findings would suggest that, rather than peaking in early adulthood, identity exploration is an ongoing process throughout the lifespan. In that context one would not expect to see significant differences between the two cohorts in this study.

These findings raise several implications for those aiming to increase uptake in STEM subjects. As the findings highlight, only a small proportion of the university students could be categorized as *achieved* identity. If one views the goal of career guidance for young people as aiming to achieve an identity in relation to their careers this could be viewed as a problem. Viewed through an Eriksonian lens this would suggest that the individual is in a state of exploration or indeed stasis when it comes to achieving an identity and has therefore not yet arrived at the desired endpoint – i.e., an achieved identity. However, viewing identity, and professional identity for that matter, as an ongoing project, achieving a desired, and rather fixed identity after a period of exploration, is not a desired or indeed expected state. Therefore is the low level of achieved identity a problem? Given the findings of this study, we argue that those charged with providing career guidance and promoting STEM careers amongst students question the assumptions underpinning a statuses model of career/identity exploration and stage theories

of identity development. If practicing professionals remain in a state of career flux in relation to their own professional identity, why should career guidance focus on steering students into particular categories of careers? If, as these findings suggest, students' career exploration is an ongoing process, the exclusive focus placed on encouraging students in upper-secondary school and undergraduate education to enter STEM careers should be questioned. While these stages are important in offering insights to students on the range of careers available to them, it would appear from this study that encouraging careers in STEM across the lifespan should be emphasized more.

These findings also call into question the very vocationally-specific nature of STEM undergraduate programs in Ireland that students must select from a very early age to enter university. For example, students in Ireland are often faced with having to select very specific undergraduate degree programmes in Science (such as Human Genetics) or Engineering (such as Mechatronic) rather than selecting broader degree categories that are less restrictive. This categorization and fragmentation is not only driven by institutional interests but also from external professional bodies driven by concerns about the lack of graduates for their specific specialisms. While efforts have been made in recent years to diffuse this narrow vocational specialism at such a young age, changes have not been significant and the status quo appears to have triumphed in the midst of this reform agenda. Oddly, as this study has highlighted, the specific and narrow nature of the degrees offered by Universities are at odds with the evolving understanding and practice of STEM careers. It could therefore be argued that this categorization and fragmentation of degrees is an impediment to increasing STEM participation in Ireland.

Policy in Ireland aims at increasing participation in STEM careers has called for an increase in outreach activities by STEM professionals to encourage both primary and post-primary students to consider careers in STEM. This has been a common practice in Ireland for many decades and has intensified in recent years, particularly in addressing the gender gap in STEM. However, as this study has highlighted, promoting a specific discipline within the STEM field, such as Physics or Chemistry, reifies a fixed and fragmented understanding of STEM which is counterproductive in the long run. Whilst we acknowledge the value of such activities and the commitment of the staff involved in their delivery, we argue that how such activities are interpreted by students and the value they have in promoting STEM careers needs to be interrogated more critically. The STEM education literature points to the ambiguity of the term and the rather vacuous nature of its application. While this is a justified critique of the term, its openness can be seen as an advantage in relation to attracting students. STEM can mean very different things to different people and this openness of the term can provide room for career mobility and change within it. For that reason, utilizing the term STEM, as opposed to more specific areas such as Science or Technology, may open up access to wider scope of career maneuverability for professionals thus making it feel a less restricted career move for uncertain students. Therefore rather than viewing students that display evidence of career moratorium or uncertainty as a problem, this instead should be celebrated as it reflects the continuous evolving nature of identity and career identity for that matter.

Conclusion

In adopting the Identity Status Model of career identity this study drew on a number of assumptions, most notably the assumption that the ideal status, an achieved identity (where the

individual feels comfortable in their career decision and therefore has a stronger chance or remaining within the profession in the long term) is the desired goal. These findings raise questions about this assumption and highlights the evolving and ongoing identity process of the individual. In that context, attempts to encourage students to arrive at an idealized, and one could argue flawed, state is a fruitless exercise as it does not reflect the majority of STEM professionals in the field. While this study was located in a single country and drew on a relatively small sample of both students and professionals from a single region, the findings nonetheless raise questions about the career statuses discourse that frame career guidance in the Irish context and in other jurisdictions. Rather than viewing Professional STEM Identity Status as the endpoint of an identity continuum, a more open and fluid understanding of professional identity may better guide research in the area of STEM and adoption of STEM careers.

Acknowledgements

This research received funding from the Johnson and Johnson WiSTEM2D Program (College and University Talent). The authors gratefully acknowledge the sponsorship provided by Johnson and Johnson to carry out this research in the University of Limerick, Ireland.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest: The authors declare they have no conflict in interests.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (University of Limerick 2016_06_28_EHS) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

References

Author. (2019). STEM and gender at university: focusing on Irish undergraduate female students' perceptions. *Journal of Applied Research in Higher Education*.

Author. (2017). Monopolising the STEM agenda in second-level schools: exploring power relations and subject subcultures. *International Journal of Technology and Design Education*, *27*(1), 51-62.

Breiner, J., Harkness, S., Johnson, C., & Koehler, C. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, 112(1), 3–11.

Buczynski, P. L. (1991). Longitudinal relations among intellectual development and identity during the first two years of college: A structural equation modeling analysis. *Research in Higher Education*, 32(5), 571-583.

Carrino, S.S., & Gerace, W.J. (2016). Why STEM Learning Communities Work: The Development of Psychosocial Learning Factors through Social Interaction. Learning Communities: *Research & Practice*, 4(1), 3.

Carlone, H.B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of research in science teaching* 48 (8): 1187-1218.

Cheung, H.Y. (2008). Measuring the professional identity of Hong Kong in-service teachers. *Journal of In-service Education, 34*(3), 375-390.

Coolican, H. (2017). *Research methods and statistics in psychology*. Psychology Press.

Creswell, J.W., & Plano Clark, V.L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications

Crocetti, E., L. Avanzi, S.T. Hawk, F. Fraccaroli & W. Meeus. (2014). Personal and social facets of job identity: A person-centered approach. *Journal of Business and Psychology*, 29 (2): 281-300.

Crocetti, E., Sica, L.S., Schwartz, J., Serafini, T., & Meeus, W. (2013). Identity styles, dimensions, statuses, and functions: Making connections among identity conceptualizations. *Revue Européenne de Psychologie Appliquée/European Review of Applied Psychology* 63: 1-13.

Crocetti, E., Rubini, M., & Meeus, W. (2008). Capturing the dynamics of identity formation in various ethnic groups: Development and validation of a three-dimensional model. *Journal of adolescence* 31 (2): 207-222.

Crossley, J., & Vivekananda-Schmidt, P. (2009). The development and evaluation of a Professional Self Identity Questionnaire to measure evolving professional self-identity in health and social care students. *Medical teacher*, *31*(12), 603-607.

Emerson, C.H. (2010). *Counselor professional identity: Construction and validation of the Counselor Professional Identity Measure*. The University of North Carolina at Greensboro.

Erikson, E. H. (1959). Identity and the life cycle. *Psychological Issues*, 1, 1-171.

Erikson. (1968). *Identity: Youth and crisis.* New York: Norton.

Erikson, E.H. (1963). Youth*: Change and challenge.* Basic books.

Gee, J.P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education* 25 (1): 99-125.

Herrera, F.A., Hurtado, S., Garcia, G. A., & Gasiewski, J. (2012). A model for redefining STEM identity for talented STEM graduate students. In *American Educational Research Association Annual Conference*, Vancover, BC.

Jones, S. R., & McEwen, M. K. (2000). A conceptual model of multiple dimensions of identity. Journal of college student development, 41(4), 405-414.

Kanny, M. A., Sax, L. J., & Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: How explanations for the gender gap have evolved over time. *Journal of Women and Minorities in Science and Engineering*, 20(2).

Kaufman, P., & Feldman, K. A. (2004). Forming identities in college: A sociological approach. *Research in Higher Education*, 45(5), 463-496.

Kier, M. W. (2013). Examining the Effects of a STEM Career Video Intervention on the Interests and STEM Professional Identities of Rural, Minority Middle School Students, Dissertation study, North Carolina State University.

Mancini, T., Caricati, L., Panari, C. & Tonarelli, A., 2015. Personal and social aspects of professional identity: An extension of Marcia's identity status model applied to a sample of university students. *Journal of Vocational Behavior, 89,* pp.140-150.

Marcia, J.E. (1966). Development and validation of ego-identity status. *Journal of personality and social psychology* 3 (5): 551.

Marcia, J.E. (1980). Identity in adolescence. *Handbook of adolescent psychology*, *9*(11), 159-187.

Marcia, J. (1994). The empirical study of ego identity. In Bosma, H., Graafsma, T., Grotevant, H. & de Levita, D. (Eds.), Identity and development: An interdisciplinary approach (pp.67-80). Thousand Oaks, CA, US: Sage.

Nadelson, L. S., & Fannigan, J. (2014). Path Less Traveled: Fostering STEM Majors' Professional Identity Development through Engagement as STEM Learning Assistants. *Journal of Higher Education Theory & Practice*, *14*(5).

Nadelson, L.S., McGuire, S.P., Davis, K.A., Farid, A., Hardy, K. K., Hsu, Y. C., & Wang, S. (2017). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education*, *42*(4), 701-720.

National Research Council. (1999). *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Washington, DC: National Academies Press.

Park, J.J., Chuang, Y.C. & Hald, E.S., 2018. Identifying Key Influencers of Professional Identity Development of Asian International STEM Graduate Students in the United States. *The Asia-Pacific Education Researcher*, *27*(2), pp.145-154.

Perez, T., Cromley, J.G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of educational psychology*, 106(1), 315.

Peticca-Harris, A. & McKenna, S. (2013). Identity struggle, professional development and career: A career/life history of a human resource management professional. Journal of Management Development, 32(8), pp.823-835.

Pillen, M. T., Den Brok, P. J., & Beijaard, D. (2013). Profiles and change in beginning teachers' professional identity tensions. *Teaching and Teacher Education*, *34*, 86-97.

Pitt, J. (2009). Blurring the boundaries—STEM education and education for sustainable development. *Design and Technology Education: An International Journal*, 14(1), 37–48.

Quirke, S. (2018). The significant narration of mathematics teachers' professional identities in an Irish mathematics education policy document, Y. & Vithal, R. (Eds.) *International Commission on Mathematics Instruction Study 24 Conference Proceedings: School Mathematics Curriculum Reforms: Challenges, Changes and Opportunities*, University of Tsukuba, Tsukuba, Japan, 25-30 November, available:https://www.mathunion.org/fileadmin/ICMI/ICMI%20studies/ICMI%20Study%2024/ICMI%20Study%2024%20Proceedings.pdf

Scott, A.J., & Knott, M. (1974). A cluster analysis method for grouping means in the analysis of variance. *Biometrics*, 507-512.