Women in STEM: How can we understand and support their career development?

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Abstract— **This Research Full Paper investigates the rich stories of a range of women in STEM through psychological and sociological frames to develop a career development framework. Current research acknowledges the lack of representation of women in STEM and reports on challenges and barriers to recruiting, retaining, and advancing women in these fields. Engineering educators recognise the need for the profession to diversify, to be more inclusive, and that innovation and entrepreneurial mindsets are required for engineering leaders in the future. Traditional career ladders are dissolving and we understand better the new models of boundaryless and protean (self-directed and values-driven) careers that span across work units, organisations and sectors, including self-employment. The future of engineering education requires learning designers to better understand how to develop the mindsets required for orienteering the many transitions in the careers of the future. If we are to support the careers of women in STEM we need to understand the nature of their career paths and choices. This qualitative research used semi-structured interviews to explore the career narratives of women in STEM, focusing on the career decision making and individual perceptions of career choices associated with career shifts or pivots. With reference to the literature on career choice, mindsets and motivations, an inductive and thematic analysis was conducted and descriptive statistics were used to analyse the data. We looked at the career paths of women in STEM in terms of their career patterns, locus of control, career context, career age and stage, career sponsorship, and their experiences in entrepreneurial ventures. A framework has been developed for characterising and understanding women's choices and the mindsets that enable success. This framework will enable us to identify approaches and tools that are useful for women to evaluate their own mindsets and design their career choices. The results can be used to inform the design of resources and interventions that support the retainment and advancement of women in STEM, developing an intentional change mindset, and supporting career choices from undergraduate level to continuous professional development education. This new framework for career development is emerging and integrates knowledge from educational research and professional experience of women to enable educators, coaches, people managers, and human resource professionals to better prepare women and organisations for the future of work.**

Keywords—career choice, women, mindsets

I. INTRODUCTION

The Australian Council of Engineering Deans indicates that the engineering profession must diversify and be more inclusive and that innovation and entrepreneurial mindsets are required for engineering leaders in the future [1]. The future of engineering education requires learning designers to better understand how to develop these mindsets and prepare a more diverse workforce which will include enabling more women to design careers that are aligned to their values, needs and goals at each career stage. With the current focus on retaining and advancing women in STEM, educators need frameworks, strategies, and tools that support and empower women.

The broad aim of this research was to contribute to the advancement of women in the technology sector with a focus on providing a framework or theoretical model that would be useful for women and those that support women's career and venture development. The research team was interested to understand the career perspectives, paths, and profiles of females in organisations leading change, launching new projects, conducting research, developing innovations in deep technologies, commercialising their intellectual property, and starting up ventures in the technology sector. Our intent was to determine how these career drivers and dynamics may be correlated with their career goals, choices, career pivots, and pathways they designed so that we could develop an evidenced-based framework to enable women to design more satisfying careers in the future of work and to enable higher education, employing organisations, and a variety of providers to offer relevant services to recruit, retain, advance, and accelerate females in satisfying employment or to launch and scale of their start-ups.

Drawing on the literature on multifaceted factors that influence career paths, we aimed to address the questions of what themes could be identified as emerging from the women's reflections on their career paths in the technology sector, and whether there were models or frameworks that could be developed to describe their patterns of career design. The scope of the research reported here was then to measure, categorise, and better understand the intentions, motivations, decision making patterns, levels of career ownership, and the number and type of career choices or changes (defined in this study as career pivots) that women make at various stages in their careers. This study made use of the career narratives of 12 women in STEM in order to better understand the internal and external resources that women accessed, and the career blocks they encountered, and to understand how they orienteered their career paths. We sought to learn how these women created intentional career change and to explore their motivations and strategies for change. The data gathered informed the individual elements of an emerging framework for career orienteering, which describes the career behaviours and career motivations of women in STEM, as they design their careers.

This paper provides an overview of the literature that looks at the career choices of women from a number of angles and then draws on this to provide a structure for investigating the career decisions of women in STEM. The research study is described and the emerging framework is presented along with our conclusions and suggestions for future work in the field.

Classical images of careers (defined and studied by [2] and [3]) are fading and contemporary careers are less often viewed as evolving via vertical or horizontal channels of career paths, but are increasingly being seen to be boundaryless careers [4], spanning different organisations, sectors, and domains, rather than a single organisation. Much research has been conducted related to the careers of women in STEM, the higher education, technology, and start-up sectors. O'Neil and Bilimoria [5] looked at the career development of women and suggest that better support is needed within organisations to foster women's career development. However, there is little research linking our understanding of the mindsets and career decision making patterns in women and the relationships that may exist between the career orienteering styles of women in engineering and information technology.

O'Neil et al [5,6] informs our understanding of work experience over a lifespan (in the form of career patterns), the personal and professional factors that affect decisions and pathways (career contexts), and the belief in career ownership. or what [5] called the 'locus of control' which is defined as the individual's belief in making career choices such as taking responsibility for career management. O'Neil and Bilimoria [5] provide evidence that career patterns and career trajectories can be shaped by organisational, societal, and relational career contexts. It is through these lenses that career decision making patterns emerge. Organisational factors that shape career decision making include organisational structures, policies, procedures, cultures, and working environments. These structures make the organisation a welcoming place for women and enable their career pathways. Societal factors represent the impact of factors outside of the domain of the organisation and include sex role socialisation, the expectations of women and society, discrimination, economic conditions and so forth. Relational factors impact the individual or their immediate support system that include spouses, partners, children, parents and managers, peers, clients, mentors, career sponsors for example. These relational factors can be positive and negative influences on career decision making patterns.

Bowles [7] defined asserting one's personal needs in the workplace as 'claiming authority'. Professionals make judgements about when to disrupt themselves to change career roles, organisations or sectors, as well as when and how they want to learn new capabilities or new disciplinary expertise. Additionally, they make decisions to ask for assistance, raises, promotions, more resources, special considerations, mentors, and career sponsors to name just a few claims of readiness or 'claims of authority' [7]. For example, in the context of a new initiative or venture, leaders claim authority when they start-up, scale-up, or seek venture capital resources and researchers claim authority when they ask for funding or laboratory space.

Literature on gender, leadership development, and career advancement explores factors such as women's claims to authority and the self-belief and the associated behaviour of asserting one's appropriateness for career advancement [8,9,10]. These claims of authority stem from the self-recognition that one's ability to exercise power is legitimate [7]. French, Raven and Cartwright [11] identified three bases of authority in the workplace: social structures that organise and distribute power in organisations; legitimising agents (for example career sponsors); and societal, organisational and individual values. Career sponsorship, as distinguished from career mentorship, is increasingly a requirement for advancement for women. This phenomenon has been studied and is seen as essential in countermanding the effects of societal and environmental factors that constrain career advancement [12,13,14]. Career sponsors are career social capital and are individuals who make their support highly visible and vouch for your performance and impact when it counts. Career sponsors are career advocates and research indicates that their roles deliver career results. These advocates must be actively recruited.

Hewlett [14] and Ilbarra et al [13] coded claims to authority as a sub-category of career sponsorship. Being able to claim your authority or right for resources is an essential developmental capability in careers and life. In reality, these requests for resources in the context for work are dependent on many variables and are a part of a negotiated process. Professionals have varying levels of motivation to focus on the commercial side of their work as measured by salaries, raises, non-salary budget resources or other monetary metrics.

The Kaleidoscope Career Model (KCM), defined by [15] is based on qualitative and quantitative research and has been recognised for its use discriminating the factors that impact career choice which include societal (e.g., discrimination, stereotyping, and government policies), environmental (organisational culture, workplace policies, supervisor attitudes and behaviours) and career choices of individuals. They liken this way of decision making to a kaleidoscope where "individuals' careers are dynamic and in motion; as their lives change, they can alter their career paths to adjust to the changes and do not rely on corporate dictates" [15]. The KCM model describes non-linear, non-traditional careers that are guided by the values of authenticity, balance and challenge that influence career decisions and these constructs have been used in this study to interpret how this career decision making model applies to entrepreneurs and the careers of the future that exhibit a variety of pathways, transitions, and interruptions across careers. Increasingly, careerists are using value-based career decision making career choices with the KCM and framing career choices based on core values. Self-employment and starting new ventures are enabling more flexibility to balance work-family demands [16,17].

Gibbings [18] describes a pattern of choices made as individual 'career leaps' or pivots that form patterns related to an individual's development of career goals, career ownership, career ambition, confidence, risk orientation. These factors are linked to the effort required to make the career leap or pivot, the clarity of their path to progression, the requirements to influence others, or self-advocate in order to establish new roles or opportunities, or the requirements to invent the future pivot without a roadmap. According to [18], career patterns demonstrate three distinct categories: career navigator, career surveyor, or career pioneers. Navigators prefer clear, well-articulated career ladders or paths of progression and have a low tolerance for risk. They prefer well-tested routes and are reluctant to experiment on unknown pathways which may not bring returns, choosing instead to leap to options that are closely related to their current role or take small, sequential steps from one role to another within the same functional area, disciplinary domain or prefer to stay employed within the same organisation, same type of organisation or same sector. Career navigators prefer career leaps to the next 'step in the career ladder'. Career surveyors

are characterized by a level of curiosity of the new or different, a higher risk tolerance, and are more comfortable with change in roles and responsibilities or change in functional areas, and were seen to push boundaries, take the less established career path, and are keen to discover new roles or options that they have not previously considered. Career surveyors view career leaps as 'destinations' or 'stepping stones' of their own design and enjoy the adventure or creating the career leap. Career pioneers are the third pattern and they explore career leaps or career options that few before them have tried before. They lean into the inspiration and the potential of creating something new, and are comfortable with risk, not concerned about ambiguous or non-existant career pathways. Pioneers are not constrained by rules or existing structures, and may choose unconventional pathways. Career pioneers see the next career leap or their options as boundless and view themselves as boundary spanners and leap to a variety of role types, sectors or organisational types. Gibbings [19] indicates that a person moves between these patterns based on external/internal context across the career and they are not necessarily developmental, sequential or fixed.

Dweck [20] uses goal orientation theory to explain career motivations, self-regulation and the impact on goal achievement in careers. Goal achievement and one's expectation of goal achievement play into our career decision making patterns. Dweck explored two mindsets that vary by their level of ego-involvement and the existence of intrinsic and extrinsic rewards for goal achievement. Goal achievement theory explains learning and career drivers, subsequent actions taken by careerists and the achievement of results. Goals are categorised as approach goals or avoidance goals. Careerists with 'growth' mindsets are focused primarily on goal achievement and those with 'fixed' mindsets are focused on performance avoidance and ego-centric goals. Using this theory, career decisions or actions can be analysed, encouraging learning, challenge, and experimentation (growth mindsets) or avoiding obstacles, effort, criticism (feedback) or risks.

There are existing models that describe approaches to intentional change that are relevant in the discussion of career decision making. Boyatzis et al [21] after years of extensive research in organisations and with individual coaching clients have emerged a theory for intentional career change which explains the larger context of change that impacts individual career pivots. Their model describes the components of the ideal self and the aspirational self that frame change process and give us an understanding of how the elements of self, including mindsets, work and individual contexts, and how individuals can access resources to support change (i.e., coaching, professional development, etc.). These researchers outline how the individual manages change by becoming aware and orienteering the positive and negative factors of change. For example, moving away from career pain points or problems and moving toward goals or other intrinsic or extrinsic gain points. Hall & Duval [22], provide us a model called the Axes of Change, which explains the change process and the stages, factors, and dynamics of change, which includes active decision making facilitated by a coach.

III. RESEARCH QUESTIONS

The rich research on career decision making gives us scope to look at the career decisions of women in STEM from a number of angles. The research questions we aimed to address were:

1) What themes can we identify as emerging from the experiences women have as they design or 'orienteer' their career paths in the technology sector?

2) What models or frameworks can we develop to describe these patterns of career design?

To begin to answer these questions, we drew from the literature described here, building on the theories of intentional career change, and identifying potential factors that may form part of the framework, identifying code structures similar to those used by other researchers: locus of control [5]; goal orientation [20]; claims of authority [7]; kaleidoscope career motivation [15]; career context and a pattern of choices related to individual 'career leaps' or pivots [18]. In addition, we looked at the age, career stage and generation of each participant, as well as, identifying whether they reported having started their own business, in order to explore potential themes that may emerge. Participants self-identified their career stage as a student (pre-career), starter (one to three years of experience), developer (four to nine years of experience) or establisher (10 or more years in their career). These stages followed the data classification procedures used by [23] and [24] and using equivalent definitions.

IV. METHODOLOGY

This study used qualitative methods to explore career narratives, including career histories and individual's perceptions of career incidents or behavioural incidents [25,26,27,28]. The narratives were gathered using semi-structured interview questions designed to encourage discussion of the career decision making patterns and individual perceptions or awareness of the career rationales related to individual career shifts or career pivots. This approach, used behavioural event interviewing (BEI) and open-ended questions to investigate career decision making choices in female leaders in higher education was used by [29]. Also included was the deployment of inductive and thematic analysis, code development and descriptive statistics in the analysis of the career narratives [5,7].

A. Sample

The data were drawn from a purposeful sample of 12 women who were selected on criteria based upon the objectives of the study, that is to study career decision making across women's career stages in the technology sector. All participants were affiliated with an urban, New South Wales university in Australia and were selected from women who self-enrolled in a four-part leadership and career development workshop series for female engineers and information technology professionals employed in the technology sector. The reasons the attendees self-reported for participating in this series were: 1) to develop a career management strategy, 2) move closer to their passions, 3) to increase career options, 4) to gain strategies to navigate career barriers, and 5) to develop their leadership brand and visibility strategy. The attendees included undergraduate and postgraduate students preparing for the job market, professional and academic university staff, and corporate leaders employed in the technology sector.

Registrants were offered the opportunity to voluntarily participate in the study which resulted in 13 participants being identified, 12 of whom were able to complete the research. The sample comprised one student, seven university staff (three being professional staff and four academic staff

responsible for teaching and research), and one corporate woman. Six of the registrants were startup founders or small business owners.

B. Data Collection and Analysis

A thematic analysis using procedures from [28] was used to collect and analyse the qualitative data in this study. Data was collected using a semi-structured interview of 1-1.5 hours including questions related to their career narratives allowing each respondent to provide a detailed career history from the moment she first considered herself a pre-professional through each progressive career decision, work transition, or choice point. The interview explored the career preparation/career timeline and career goals, beliefs, and rationale for decision making. Some interviews were able to be held in person, while others were completed remotely due to the COVID-19 disruption.

C. Coding Procedures

For the qualitative data collected in the career interviews, codes were developed based on theory and the inductive method [28]. The literature review informed the unit of coding for the career history, noting awarenesses, framing of responsibility, goal, motivations, decision making rationale and actions taken that resulted in a discrete career choices [30,31].

The unit for coding was each discrete career decision or career pivot. Career pivots were also used as an indicator with the number of pivots classified as low (0 to 5 pivots), medium (5 to 10 pivots) or high (greater than 10 pivots).

Dominant career decision making patterns were derived by breaking down the career narratives into these discrete career decisions or pivots and each coded using the definitions used by previous researchers or developed as required from the data in this study. Codes were counted, patterns emerged and dominant patterns were defined by the majority pattern exhibited by the respondent in each code category. Where the code category involved a count of events, the data were coded in ranges of high, medium and low.

a) Career locus coding: To uncover the level of responsibility being taken to self-manage one's leadership and career development, a sub-sample code structure was developed which aligned with O'Neil and Bilimoria's (2005) definition of career locus. Women in their study were categorised based on the evidence within their career narratives for locus of control, which is defined as a self-directed orientation or externally-directed, based on the view that personal effort, focus, and planning is a source of success as opposed to success coming from chance or other external factors.

b) Goal orientation coding: Each coding unit was classified according to whether it exhibited Dewck's growth mindset, characterised by motivations toward goals and participants' perceptions of their own capabilities as continually emerging and developing toward mastery.

c) Claims of authority coding: Claims of authority were coded for any pivot that indicated agency in the transition, such as changing roles, organisations or sectors, and learning new capabilities or new disciplinary expertise. Claims to authority included decisions to ask for assistance, raises, promotions, more resources, special considerations, mentors or career sponsors. In the context of a new initiative or venture, participants indicated a claim to authority when they startup, scaleup, or seek venture capital resources. Claims to authority were counted as discrete (and equal) events and classified as low (0-1 claim), medium (2-4 claims) or high (more than 5 claims).

d) Kaleidoscope career motivation (KCM): The coding structure for KCM followed [15], enabling the respondents' career pivots to be categorised based on the need for their pivot to be aligned with their 'quest' for authenticity, balance or challenge.These researchers defined authenticity as the individual's quest to be genuine or true to him/herself and to the use of value-based decision making which aligns mindsets, attitudes, and behaviours to personal values. Balance is defined as a person's need for equilibrium or balance between roles, relationships, and other aspects of life. The researchers define the need for challenge as a driver for career decision making as the need for stimulating work, career advancement and self-worth.

e) Career context coding: Career context was coded using O'Neil and Bilimoria's [5] coding structure in which one of four factors drive the motivation for career pivots: 1) organisational, 2) societal, 3) relational and 4) self. These factors can be positive (for example career sponsorship or mentoring) or negative (such as a difficult or non-supportive supervisor, workplace bully, or perpetrator of sexual harassment or abuse).

f) Career pattern or orienteering: This coding structure leveraged Gibbings' definition of career leaps or pivots, allowing the respondents to be categorised as career navigators, surveyors, or pioneers. Each pivot was coded according to whether it displayed the characteristics of a navigator, surveyors or pioneer.

D. Coding Reliability

A sub-sample of the 12 interviews was randomly selected for career decision making pattern coding by two researchers. The two coders went through an iterative process and four rounds of testing, discussion, calibration, and clarifying of the units of measure, coding definitions and coding reliability. Codes were developed, definitions tested, and then the reliability of coding was tested against additional interviews. Given the high agreement rates after the initial iterations, the career timeline coding was determined to be reliable and the remaining interviews were coded. The coders checked the work of their partner for reliability.

V. RESULTS AND DISCUSSION

The results of analysis of the coded interview data is summarised in Figure 1 for those factors demonstrating variations.
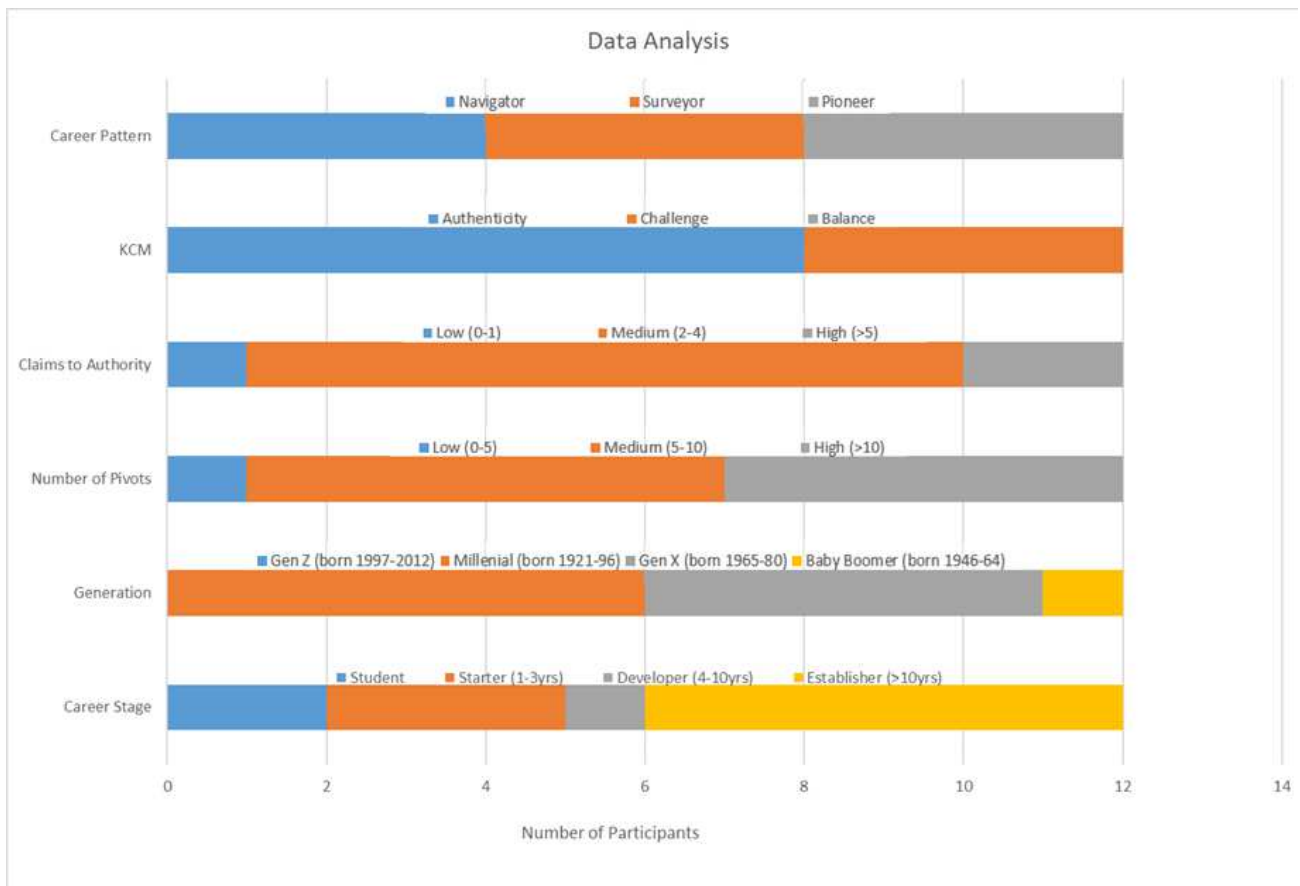
Fig. 1. Results of interview data coding

The results of the data analysis demonstrate that career pivots, as narrated by the women in the study, was a valuable unit of coding in order to determine the factors that affected the decision making of the women at each self-identified career pivot. Including this unit of analysis in a framework will allow future studies to collect data that is meaningful and comparable across projects.

Following the iterative coding procedures for each career pivot, there were some factors that were overwhelmingly consistent between the women in the study at every career decision point. All of the 12 women in this sample exhibited career responsibility defined here as career ownership and a self-directed locus of control. These women expressed responsibility to cause opportunities, career shifts or career progression. All women were also coded as having a "growth mindset" for the goal orientation. Respondents with a growth mindset move toward their goals, inspired by the challenge of learning and the belief that mastery can be achieved through effort or persistence. Obstacles were seen to be navigated through fortitude and career effort was expected. These respondents viewed feedback as critical to the learning process. We postulate that these findings may be a result of the sample being selected from women participating in a self-enrolled program on career development activity, which indicates a self-directed approach and the context for career decision making and indicates the willingness to put effort into learning, characteristic of a growth mindset. While the literature review indicates that career ownership is critical, more research is required to confirm the inclusion of these factors in the emerging framework. A future, more fine-grained measurement and analysis of mindsets (such as Duval's) may uncover variations useful for the framework.

As expected, the career stage varied with generation and age, all participants having entered the workforce from school or tertiary study. Age and career stage correlated with the number of pivots as would be expected for longer careers and our sample did not provide any indication for the anecdotal descriptions of younger generations making more career pivots or claims to authority.

The career context whereby the pivots were analysed for one of four motivating factors, was overwhelmingly classified as "self-motivated" for 11 out of the 12 women and within each narrative very few examples of other motivators were coded. This suggests to the researchers that the coding using this factor is not detailed enough to detect differences in motivating factors using the narratives. It is reasonable to expect that even women who are self-motivated will at times make decisions motivated by other factors. The researcher's propose that there is scope to look at more fine-grained tools that measure preferences and motivation that may give greater insight into this factor of women's career decision making and that the proposed classification here is not useful for a framework analysing motivations.

In support of this, the KCM coding resulted in eight women coded for "challenge" and four for "authenticity" while none were coded for "balance". The underlying data at each pivot showed more variation however. For example, the women deployed different levels of career clarity or planning and different levels of motivation for achievement. The

women in the study had different motivations to avoid career problems and had differing levels of flexibility and career risk taking. Many were fulfilling multiple life roles—some women had fewer degrees of freedom to risk career pivots, other women did not make pivots that were not aligned with their core values. The researchers argue that, based on this, KCM may prove to be a useful factor in analysing women in STEM's career choices with further study into motivations as recommended.

A rich source of information was the career orienteering patterns of navigator, and pioneer exposed in the narratives. As Gibbings described, women made decisions demonstrating different patterns across their careers depending on the context, but in almost all cases there was a dominant decision making pattern for each participant [19]. Including the career orienteering pattern in a framework looking at how women design their careers will give them an understanding of their current patterns for orienteering themselves with each decision and allow educators to support them with tools that enable this pattern or help them shift toward another pattern, if they desire.

Our data indicate that the women in the sample had varying levels of career ownership as measured by the number and type of claims of authority. The ability to self-advocate or claim your authority or right for career or project resources is an essential developmental capability in careers. In reality, these requests for resources in the context for work are dependent on many variables and are a part of a negotiated process. Professionals have varying levels of motivation to focus on the commercial side of their work as measured by salaries, raises, non-salary budget resources or other monetary metrics. While the description of what constitutes low, medium, or high number of claims to authority is not conclusively supported, the variation does provide insight for women looking to design careers and make use of tools and strategies such as claims to authority that have been and can be successful in their careers.

VI. Proposed framework and future work

What emerges from our analysis of the narratives of women in the technology sector builds upon existing frameworks for career decision making that may be used for intentional career change and which enhances our understanding of the decision making that underpins these frameworks. Building from the starting point that these women have an appreciation or awareness of the self within the career or employment context and already have a level of responsibility for career design and the framework that emerges includes the:

- Looking at careers as a series of pivots, each of which involves its own context, decisions making pattern, motivation, resources and support requirements.

- Number and types of claims to authority made over a career and at each career pivot.

- Motivations behind each pivot (according to the KCM model).

- Career decision making pattern of navigator, surveyor, or pioneer at each pivot and the orienteering pattern which dominates over the career.

The research, as highlighted by the KCM coding, indicates that there should be future work looking at the motivations that drive each career pivot and contribute to career decision making patterns.

This model has implications for how we prepare women in STEM and support them throughout their careers, for example, by building awareness of career options and orienteering styles (career pattern), increasing self-awareness and self-trust in making career choices based key indicators (motivations), focusing career intentions, and clarifying the process of developing as a professional, such as being comfortable in accessing resources and asserting need appropriately (self-advocating and claiming of authority). For engineering education, we can look to this framework as a guide for embedding experiential career orienteering models into learning designs and learning pathways, build awareness of different career choices, and orienteering resources, as well as guiding the development of leadership, venture development, coaching and mentoring programs.

VII. Conclusion

This research has emerged a framework for intentional career change which suggests that career decision making can be viewed as a series of pivots with associated self-advocacy (claims to authority), motivations and career patterns of navigator, surveyor or pioneer. The framework illuminates the process of change for the individuals, employers, and for educators or facilitators of learning. Making the mindsets visible through measurement and feedback loops enables both the careerist and the aspiring startup founders to understand the key capabilities for professional and venture growth and how to develop these capabilities over time. It can be used to enable work readiness and career development resources that support women's career choices, decision making patterns, and career paths in the technology sector, and to illuminate their career motivations, decision making patterns, resources and support requirements. The significance of this research is its focus on the needs of women across their careers and how they create their career concept or vision, and how they orienteer their careers.

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