Better late than never? Identity work, trajectories, and persistence of latecomers to science

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Abstract

Despite increasing efforts to find ways to provide opportunities for all students to access and succeed in science, one group continues to be overlooked by researchers: students who enter through alternative routes rather than directly from high school, or *latecomers to science*. Latecomers are less likely to persist in postsecondary science. Accordingly, the overarching objective of this dissertation is to gain a better understanding of latecomers' persistence. This dissertation includes three interrelated manuscripts, which together represent an 18 month embedded case study of 25 latecomers' identification with science at Island College, a Québec Collège d'Enseignement Général et Professionnel (CEGEP). Throughout the dissertation, which is rooted in theories of social practice, identification is theorized as akin to motion. Dominant forces, in the form of cultural models, exerted by the figured world of the science program create patterns of acceleration towards or away from science, thus supporting or hindering latecomers' persistence as their science identity trajectories gain or lose momentum. This theoretical framework and way of representing identification over time offers new perspectives on persistence in science.

This dissertation begins by examining the persistence of 18 latecomers in the Island College science program. Only eight of the 18 persisted through their first year. To gain insight into challenges to their persistence, a new conception of identity trajectories formed through participation in figured worlds is used. This facilitates an exploration of how nine latecomers' self-authorings in relation to science were constrained by or improvised with the resources available in the figured world of the science program. Findings show that latecomers' identification with science, and thus persistence, was greatly constrained by two cultural models: good science students follow a paradigmatic sequence of courses and earn good grades.

Next, to investigate how more resources can be made available, latecomers' identity work in their courses and its contribution to their identity trajectories are examined. Following two persisting latecomers (from the initial 18) as they participated in their second and third semesters of science, it is shown that, although they found ways to engage in successful identity work, the prevalence of teacher-centred and sink-or-swim cultural models of learning limited their ability to identify with science. It is argued that active learning and social constructivist practices would offer more resources for successful identity work, affording latecomers' persistence.

Lastly, this dissertation explores the possibility of liberation from some of the constraints of the figured world of the science program through latecomers' co-construction of new resources in an online forum in which 25 latecomers participated, including the initial 18 latecomers. Conducting a critical discourse analysis of one thread, it is shown how four latecomers co-constructed an alternative cultural model and formed solidarity. Using this model in conjunction with their solidarity, the latecomers successfully positioned themselves in the elite figured world of science despite histories of disidentification. They also reified the result in a form that could potentially support future identification with science. Aspects of the online forum that supported this co-production are explored.

Overall findings suggest that latecomers' persistence would be better supported by making available a wider array of resources for identifying with science. Such resources include those which actively encourage latecomers to (a) gain interest in science, (b) ask questions in and out of class, (c) interact with each other in science-related contexts and discuss their past and present struggles in science, and (d) draw on the resources they bring with them from participation in other figured worlds. Implications for practice are discussed.

Résumé

En dépit des efforts pour trouver des méthodes permettant d'offrir à tous les étudiants l'opportunité d'accéder à la science et de s'y épanouir, un groupe continue d'être ignoré par les chercheurs : les étudiants qui arrivent par des chemins alternatifs à l'université aussi appelés Retardataires de la science. Ces retardataires ont moins de chances de poursuivre en sciences dans le supérieur. L'objectif principal de cette dissertation est d'avoir une meilleure compréhension du processus qui leur permet de poursuivre. Cette dissertation comprend trois manuscrits corrélés, qui couvrent ensemble une étude de cas de 18 mois portant sur l'identification de 25 retardataires en science à l'Island College, au Collège d' Enseignement Général et Professionnel (CEGEP) de Québec. Tout au long de cette dissertation, qui prend ses racines dans les théories de la pratique sociale, l'identification se théorise comme le mouvement. Les forces dominantes, sous la forme des modèles culturels, exercées par les modèles de création des programmes scientifiques, rapprochent ou éloignent de la science et ainsi supportent ou entravent la persistance des retardataires à mesure que leurs trajectoires scientifiques avancent ou reculent. Ce cadre théorique et cette représentation de l'identification dans le temps offrent de nouvelles perspectives sur la persistance en science.

Cette dissertation examine d'abord la persistance de 18 retardataires du programme scientifique de l'Island College. Seuls 8 des 18 retardataires ont terminé leur première année. En présentant la construction des trajectoires identitaires formées par leur participation dans ce monde figuré, les défis rencontrés par les retardataires dans la poursuite de leurs études sont étudiés à travers l'exploration des réalisations de neuf retardataires sur leur relation à la science, ils ont été contraints ou ont improvisé avec les ressources disponibles dans le monde figuré du programme scientifique. Nous découvrons que l'identification des retardataires avec la science, et donc leur persistance, est très influencée par deux modèles culturels : les

étudiants doués en science suivent une séquence paradigmatique de cours et ont des bonnes notes.

Par la suite, pour approfondir notre étude de la mise à disposition de ces ressources, nous examinerons le travail identitaire des retardataires dans leurs cours et comment il participe à leurs trajectoires scientifiques. En suivant deux retardataires persévérants (qui faisaient partie du groupe initial de 18 personnes) au cours de leurs deuxième et troisième trimestres scientifiques, on montre que bien qu'ils aient réalisé un travail identitaire réussi, la prévalence d'un modèle d'apprentissage centré sur l'enseignant et de type « Marche ou Crève » a limité leur progression. Nous soutiendrons que des pratiques pédagogiques et sociales constructivistes actives donnent plus de moyens pour un travail identitaire réussi, aidant à la persistance des retardataires.

Pour finir, cette dissertation explore la possibilité de la libération de certaines contraintes de ce monde figuré des programmes scientifiques au travers de la co-construction de nouvelles ressources dans un forum en ligne auquel ont participé 25 retardataires, y compris les 18 retardataires d'origine. En réalisant une analyse critique sur une discussion du forum, on a démontré comment quatre retardataires ont co-construit un modèle culturel alternatif et font preuve de solidarité. En utilisant ce modèle conjointement avec la solidarité, les retardataires ont réussi à se positionner dans l'élite du monde figuré de la science malgré un historique de désidentification. Ils ont aussi reproduit le résultat sous une forme qui peut potentiellement aider à de futures identifications avec la science. Nous explorons ainsi les aspects du forum en ligne qui soutiennent ces coproductions.

Les conclusions générales suggèrent que la persistance des retardataires serait mieux supportée en mettant à disposition une large gamme de ressources pour s'identifier avec la science. De telles ressources doivent contenir celles qui poussent activement (a) s'intéresser à la science, (b) à poser des questions pendant et en dehors des cours, (c) à interagir les uns avec les autres dans un contexte scientifique et à discuter de leurs problèmes passés et présents en science et (d) à dessiner les ressources qu'ils importent de leur participation dans d'autres mondes figurés. Nous discuterons des implications pratiques.

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Contributions of Co-Authors and Remarks on Style

This thesis follows a manuscript-based format. As is expected in this format, there is some repetition in the text. As primary author of every chapter, I conceptualized and carried out all aspects of the research and also wrote the current dissertation in its entirety. Chapter 2 is co-authored with Dr. Gale Seiler and has been published in the Journal of Research in Science Teaching (2013). Chapters 3 and 4 are in preparation for submission to peer-reviewed journals. As my doctoral supervisor, Dr. Gale Seiler has served in an advisory capacity during the conceptualization of this research, formulation of the research questions, and writing of the dissertation. She has provided guidance, feedback and critique throughout the project. For Chapter 2, Dr. Seiler contributed to the initial drafts and to the publication revision process, working closely with me to address reviewers' comments.

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Chapter 1: General Introduction

Despite national and global efforts to increase engagement in science, one group of marginalized students has continued to go largely unnoticed by science education researchers: students who enter postsecondary science through non-traditional routes (Mueller, 2008). I term these students *latecomers to science*. Latecomers to science differ from traditional science students in that they often have histories of academic difficulty in science, meaning they have received low or failing grades in one or more courses and/or they did not follow the traditional sequence of courses through high school leading directly into postsecondary science. [1] Both of these differences have been found to correlate with reduced persistence in postsecondary science (American College Testing, 2006; Chen & Weko, 2009). Research is therefore needed to explore their complex educational paths to learn how to better support their persistence.

A significant amount of research has been conducted on post-secondary enrollment and persistence over the last 40 years (Ohland et al., 2008), the majority of which uses quantitative methods to develop and refine models for broad student populations (e.g., Bean, 1980, 1985; Cabrera, Castaneda, Nora, & Hengstler, 1992; Tinto, 1975, 1993). Research on persistence specifically in science education tends to focus on understanding attrition, or leaks in the science *pipeline,* occurring near the end of high school into and through undergraduate degrees (e.g., Chen & Weko, 2009; Maltese & Tai, 2011). Although such studies usually approach persistence quantitatively to gain an expansive view of the pipeline, a few have taken a more ethnographic approach in order to explore the experiences of individual students, thus providing deeper insight into the processes underlying students'

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[1] Here, the term *course* is used in the North American sense, to mean one component of the overall science program, generally running over one semester with a classroom and lab component.

persistence. In particular, two studies stand out in this field: Seymour and Hewitt (1997) and Tobias (1990). Seymour and Hewitt's expansive study (1997) used interviews, surveys, and administrative data to conclude that issues such as lack of guidance, poor teaching, and the competitive nature of undergraduate science programs contribute to large numbers of students switching out. While groundbreaking, this research did not address the intensely contextual nature of individual student's lives. In contrast, Sheila Tobias (1990) addressed students' individual contexts by paying high achieving non-science students to audit several university science courses. Using their journal entries to explore why such students were not willing to pursue science, Tobias found the problems included poor teaching, large class sizes, lack of creative outlets, and a lack of critical thinking. However, by relying on students not enrolled in the science program, Tobias' study did not provide insight into the role of the science program itself. And, importantly, neither of these studies looked at science students who enter through non-traditional pathways, that is, latecomers to science.

There has been a recent increase in critique of the science pipeline metaphor's inability to address the complexity of enrollment and persistence in science (e.g., Aschbacher, Li, & Roth, 2010; Hanson, Schaub, & Baker, 1996). In particular, Xie and Killewald (2012) drew attention to pipeline research's failure to account for students who switch into science from non-science degrees. A similar oversight exists for students who access postsecondary science late, rather than directly out of high school. By studying latecomers to science, this research answers the call for research into the increasingly complex educational pathways that students are following (Finnie & Qiu, 2008; Xie & Killewald, 2012). The overall goal of this research is to better understand the persistence of latecomers to science in their post-secondary science program. Theorizing an individual's persistence in college science as closely linked to his or her identification with science, this research takes the overall form of an embedded case study of latecomers' identification with science in the science program at

Island College, an Anglophone Québec Collège d'Enseignement Général et Professionnel (CEGEP).[2, 3]

The remainder of this chapter provides an overview of the theoretical framework and methodology used in this dissertation. Throughout the overview of the theoretical framework, examples are provided of how various concepts have been already used in the science education literature and areas are highlighted where there is room for extending the current theoretical conceptualizations to improve understandings of persistence in science. Because this dissertation is presented in manuscript-based thesis form, the theoretical framework and methodology will be described in significantly more detail as they are applied in the manuscripts which appear in chapters 2-4.

Overview of Theoretical Framework

Founded on sociocultural theories of practice, the overarching goal of this research to better understand latecomers' persistence is realized through the theoretical lens of identity. Drawing from Holland, Lachicotte Jr., Skinner, and Cain's (1998) pioneering work on identification in figured worlds and adapting the concept of patterned identity trajectories from Wenger (1998), this research understands latecomers' persistence to be closely linked to their ability to identify with science over time. As will be explained, this ability is both constrained and afforded by the resources made available by the figured world of the Island College science program.

The connection between identity and persistence in higher education has been hinted at throughout the general persistence literature. For example, much of the foundational work on persistence (e.g., Tinto, 1975) recognized college students' persistence to be closely

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[2] A pseudonym is used for the CEGEP.

[3] The role of CEGEP's in the Quebec education system and their comparative position to other colleges is described later in this chapter.

related to their ability to take up and enact the shared values, behaviours, and norms of the social world within which they are participating (Eimers & Pike, 1997). Although these approaches come from a largely psychological perspective (Koyama, 2007), they share the basic understanding of persistence as linked to how an individual sees him/herself and is seen by others in relation to the educational context, as well as the longitudinal process of *learning* and *becoming* through participation within that educational context. However, in such literature, specific reference to processes of identification tends to be limited to the interaction between racial/ethnic identities, which are viewed as relatively stable, and the values and norms of the program under question.

In science education, researchers are increasingly relying on identity to understand how students learn and participate in science (Ardenghi & Jackson, in press; Shanahan, 2009), and thus the connection between persistence and students' identification with science is more developed. For example, Aschbacher et al. (2010) showed that students who were able to consistently identify with science over time and across contexts were more likely to persist through high school and into postsecondary science.

Because of the demonstrated usefulness of identity for theorizing the relationship between individuals and their social world, it is often used in sociocultural studies exploring issues of marginalization (e.g., Brickhouse & Potter, 2001; Carlone & Johnson, 2007; Elmesky & Seiler, 2007; Malone & Barabino, 2009; Rahm, 2008). In terms of postsecondary science, a number of studies have applied the sociocultural lens of identity to students' persistence (e.g., Buck, Leslie-Pelecky, Lu, Plano Clark, & Creswell, 2006; Carlone & Johnson, 2007; Hunter, Laursen, & Seymour, 2007; Johnson, Brown, Carlone, & Cuevas, 2011; Tate & Linn, 2005; Tonso, 2006). Notably, Carlone and Johnson (2007) connected identity and persistence by considering not only the resources that 15 women of colour brought with them from pre-college experiences, but also how their daily interactions and experiences in college, particularly recognition as a science person that they received from meaningful others such as teachers, "accrete[d]" (p. 2011) to support their persistence in science. This concept of accretion of experience is elaborated on in reference to identity trajectories later in this section and is further explored in Chapter 2, which explores latecomers' identification with, and persistence in, science over the course of their first year in the Island College science program. Importantly, because they drew from interview and email data, Carlone and Johnson did not explore how actual participation in science-related practices contributed to such experiences of recognition. This is one area the current research addresses, drawing on course observations and other data to explore how latecomers' participation in their science courses led to positive recognition, or not, from their teachers (Chapter 3).

Despite gaining prominence in science education, there is still disagreement about how identity should be conceptualized (Shanahan, 2009), with some studies taking a more stable view of identity than others (Ardenghi & Jackson, in press). In this research project, identity is conceptualized as being continually constructed in social interaction, rather than as having a stable component that one can carry across contexts and time. To promote this perspective, active terms are used, such as identification, identify, and identity work, rather than the noun *identity* which has connotations of being something that individuals possess. In particular, the term *identity work* reminds us of "the tension between the work that individuals do and how that work is taken up by others over time and space" (Barton et al., 2013, p. 38). This conceptualization of identity as fleeting and unstable allows an understanding that, while latecomers' identification with science is constrained by societal structures, there is room for agency, that is, for latecomers to leverage resources to "act upon, modify, and give significance to the world in purposeful ways, with the aim of creating, impacting and/or transforming themselves and/or the conditions of their lives" (Basu, Barton, Clairmont, & Locke, 2009, p. 355). In this way, latecomers' persistence in science is theorized not as predetermined and predictable, but as emerging through participation in their science program, as latecomers construct a unique sequence of experiences identifying with science over time. This is referred to here as their *science identity trajectories*, as will be discussed later. First however, the related concepts of identity work and figured worlds are discussed.

Identity Work

Identity work is a complex social process of positioning and recognition, where one draws on the available resources to bid to be recognized as a certain type of person. This is often referred to as taking up *a subject position*, (Davies & Harré, 1990; Gee, 2011b; Holland et al., 1998). However, simply bidding to be recognized as a certain type of science person is not sufficient for identification with science. One's bid must be recognized by others as credible (Carlone & Johnson, 2007; Gonsalves, 2010). Also, in some situations, the process is less about how the individual bids are recognized, and more about how others position an individual and, in turn, how the individual responds to these imposed subject positions (Davies & Harré, 1990). In either case, identification is a continual negotiation between individuals and social contexts.

An important aspect of identity work is the self-authoring that occurs as individuals make sense of their experiences. This process is not separate from the process of positioning and recognition, but rather, drawing on the available resources, individuals are constantly narrating (e.g., talking, writing, or thinking about) their past, present, and/or future, and in doing so, they position, or *author*, themselves in certain ways (e.g., as moving towards or away from science). Hence, identity work is an intricate process in which individuals are constantly positioning themselves in interaction with others, while simultaneously making sense of their experiences and re-interpreting them to find new ways to position themselves.

Also adding to the complexity of identity work, the resources individuals draw upon to make sense of their experiences, position themselves, and negotiate recognition are not simply drawn from thin air. They are made available by the relevant figured world(s) and are acquired (learned) by individuals as they participate and use these resources in activities organized by that figured world (Holland et al., 1998). The following section explains what is meant by the term *resources*, and where such resources come from.

Figured Worlds and Resources

The concept of figured worlds provides an understanding of how identification processes shape and are shaped by social structures, while remaining open to the possibility of change. A figured world is “a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others” (Holland et al., 1998, p. 52). Figured worlds exist at many different scales, often in a nested or overlapping arrangement (Lemke, 2000; Reveles, Cordova, & Kelly, 2004). Although the figured world of the Island College science program is the main focus of this dissertation, other relevant figured worlds are also considered. For example, Chapter 2 explores how the figured world of the science program is connected with the figured world of the Québec education system and the figured world of science. Similarly, Chapter 3 explores how, although each science course in Island College can be considered a unique figured world, their overall homogeneity contributes to and usually reproduces the larger figured world of the science program.

Figured worlds are continually reproduced by our use of the resources that are acquired as we participate in activities organized by that figured world (Holland et al., 1998). Among other forms, these resources can take the form of cultural models, which are “mental/emotional knowledge structures” (Holland et al., 1998, p. 297) that help individuals *reframe* past experiences in order to position themselves and others within the figured world.

Holland et al. explained that, "one's history-in-person is the sediment from past experiences upon which one improvises, using the cultural resources available, in response to the subject positions afforded one in the present" (p. 18). This means that latecomers cannot disregard their histories of disidentification with science. Instead, they must use the available resources to reinterpret their histories in ways that help, rather than hinder, their identity work in science. By shaping the self-authoring that latecomers do as they make sense of their experiences in science, cultural models (learned through participation in the figured world of the science program and the accompanying identity work in interaction) can also guide future participation in science and thus have longer term implications for latecomers' identification with, and persistence in, science. Hence, the resources latecomers acquire have the potential to afford not only their *current* positionings of self and others, but also *future* identity work in science.

Compared to identity, the concept of figured worlds is only beginning to gain ground in science education research (Seiler, 2013), particularly in postsecondary science studies, where only one study stands out. Tonso (2006) represented a campus engineering community as a figured world and documented powerful cultural forms of scientist and engineer that permeated that world and constrained the ways in which students could identify within that figured world. Similar to Tonso's work, this dissertation explores how the dominant cultural models of the figured world of the science program constrain latecomers' ability to identify with science by making available resources that tend to position them negatively in relation to science. Although not focused on science, Hungerford-Kresser and Vetter's (2012) use of figured worlds also shares important similarities with this dissertation research. They described the identity negotiations of a Latino student at university, showing how, in the figured world of the university, discourses acted as powerful constraints to the student's ability to successfully position himself within the figured world.

A brief look at the non-postsecondary science research provides a broader idea of how figured worlds can and have been used. Rahm (2007) looked at the figured worlds of science constructed by individual students, showing how they varied significantly between students. In understanding individuals as having their own figured worlds of science, Rahm varied from how most researchers have used the concept, including how figured worlds are theorized in this dissertation. However, her approach offered further insight into how marginalized students' ability to identify with science is often constrained by the resources made available by figured worlds of science. It also showed how resources for identification with science can be constructed if we, as teachers and researchers, build upon students' prior understandings of science through talk, action and reflection. This latter insight provides theoretical support for the interactive and reflective data collection methods used throughout this dissertation research, as will be elaborated on later (e.g., journal entries and online forums focusing on students experiences in and understandings of science). This concept is further explored in Chapter 4.

More aligned with how figured worlds are used in this dissertation and elsewhere, Tan and Barton (2008b, 2010) conceptualized classrooms as multiple figured worlds and explored how they were shaped by teachers and students in ways that can offer a range of possibilities for students to author their identities. Similarly, Carlone, Haun-Frank, and Webb (2011) viewed school science learning in 4th grade classes as figured worlds, showing how, when resources are used in new ways and new resources are created, figured worlds can be altered to produce more equitable opportunities for all students. These uses of figured worlds further demonstrate their utility in theorizing not only how latecomers' identification with science may be constrained by the figured world of the science program, but also how latecomers may participate in ways that support their identification within the figured world. They also suggest that it is possible for teachers and other stakeholders, besides the latecomers themselves, to enact changes to the figured world in order to better support latecomers' persistence.

This concept of liberation from the constraints of figured worlds is supported by the theoretical understanding that, despite the highly reproductive nature of figured worlds, there is also the possibility of resources being used in ways that can liberate participants from the constraints. Holland et al. (1998) explained, "The constraints are overpowering, yet not hermetically sealed" (p.18). Studying such moments of improvisation and liberation allows us to understand how latecomers may resist the constraining structures of privilege and influence that populate the figured worlds of science. Such improvisation is often referred to as agency on the part of the individuals' working towards liberation (Holland et al., 1998; Sewell, 1992). This concept is drawn on throughout this dissertation, but in particular in Chapter 4, which explores latecomers' co-construction of resources to help them identify with science in an online forum.

Science Identity Trajectories

To understand how to better support latecomers' persistence in postsecondary science, it is important to not only look at latecomers' identification in-the-moment, but how such identification changes, or doesn't change, over time. The importance of looking at identification with science over multiple time scales has been emphasized in recent literature (e.g., Johnson et al., 2011; Lemke, 2000; Varelas, House, & Wenzel, 2005; Wortham, 2006). However, as Barton et al. (2013) noted, it is a difficult task. To assist in this undertaking, I adapt Wenger's (1998) concept of identity trajectories to the case of latecomers persisting in postsecondary science.

A science identity trajectory is an individual's unique sequence of science-related identity constructions. Researchers can never know the countless moments of identity construction during the span of a year or a semester. It is possible, however, to recognize general patterns of identification over time, termed here as *trends* in one's identity trajectory. Chapter 2 elaborates on and illustrates the three trends that latecomers to science can construct: inbound trajectories, outbound trajectories, and peripheral trajectories. Inbound trajectories, which represent an overall pattern of increasing identification with science and thus persistence, are considered the most desirable outcome for latecomers to science and are referred to throughout all three chapters. This is not because of any allegiance to the notion that science is a better postsecondary choice than other fields, but because achieving a future in science is the expressed desire of latecomers to science, as shown by the extra time and effort that they have already put into trying attain this future before even entering their postsecondary science program (e.g., taking adult education courses, leaving other programs or jobs).

Trends in trajectories form because the construction of an identity trajectory is a continual process of negotiation in which one acquires and uses resources that can assist or hinder in future instances of identity construction. Taking a Neo-Vygotskian perspective, Holland et. al (1998) explained that figured worlds exert directive forces, that is, they encourage people to act in certain ways, as, through participation in that figured world, the person comes to learn, or personalize, the available resources, which then become part of the person's "higher mental functions" (p. 100), guiding their actions. Accordingly, as latecomers build up resources, it becomes easier or harder to identify with science. Such a concept has been described in many ways, such as Holland and Lave's (2001) *thickening of identity*, Wortham's (2006) *emergence of social identification*, and Carlone and Johnson's *accretion of experience* (2007). In Chapter 2, it is shown how this can be conceptualized as the *momentum* of a science identity trajectory, which serves to keep the trajectory moving towards or away from science, making it difficult to shift the trend of a trajectory when momentum is great (Wenger, 1998).

Taking the conceptualization of identity as a continual process or (re)production one step further than has been done in the literature, identification is analogized to *motion,* throughout this research. As latecomers participate in activities organized by the figured world of the science program, and also as they make sense of these experiences through narration, they are positioned and recognized as *moving* towards or away from science. In Chapter 2, this is extended to an analogy of identification as akin to a *velocity* vector, which describes the speed and direction of motion/identification at a specific moment. Conceptualizing identification as velocity has various theoretical and methodological strengths in relation to identity trajectories that are elaborated on in Chapter 2. Notably, it provides a language for discussing how the figured world of the Island College science program exerts *forces* on latecomers' identity trajectories. The concept of social forces shaping one's identification has been used many times, both in and out of science education (Buxton, 2005; Gee, 2000; Goldston & Kyzer, 2009; e.g., Holland et al., 1998; Johnson, 2012; Mishler, 1999). This new way of talking about these forces and their interaction with identification, which is used throughout the dissertation, allows us to show how figured worlds can *accelerate* latecomers towards or away from science, affecting their momentum and thus having implications for their persistence. Such a language is important for maintaining theoretical coherence amongst identity related concepts throughout one's research (Ardenghi & Jackson, in press).

Context

CEGEPs are public colleges that provide two-year pre-university programs, three-year career programs, and technical programs. In Québec, secondary school ends after Grade 11, after which students can attend CEGEP. The two-year CEGEP *pre-university science program* is comparable to 12th grade and first year university in the rest of North America. In Québec high schools, students are streamed into advanced or regular science and math courses in Grade 10 depending on their marks.[4] To access a pre-university science program directly, students must earn at least 70% in the Grade 11 advanced math and science courses. If students have never taken the prerequisite courses (or have failed but previously enrolled in a different CEGEP program), they may access the CEGEP *preparatory science program*, in which they have two semesters to complete the prerequisites by taking what are called *make-up courses*.[5] If they successfully complete these courses, they will be accepted into the pre-university science program. These are the students I call latecomers to science. References to the *science program* refer to both of these programs at Island College: the preparatory science program and the pre-university science program, the former of which is intended to feed directly into the latter.

Impetus

This research was first conceived when I was assigned to teach a make-up Grade 11 physics course for the Fall semester, 2009. When I spoke with my colleagues about my students' needs, the general consensus was that these students did poorly in the past and were therefore unlikely to succeed now. Unhappy with this deficit view of my soon-to-be students, I looked to the literature for more support, but soon realized that latecomers to science were not yet on the science education research radar. I designed a research project that could better inform my teaching, help my current and future students, and introduce latecomers to science to the science education research agenda. That first semester taught me the extent to which

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[4] This process has changed slightly now, but it applied for the participants in this research.

[5] If students earn between 60-69% in the high school prerequisites, then they must take bridging courses in CEGEP before moving on to the regular science program. This study does not look at students who are only taking bridging courses, but instead focuses on those who must take one or more make-up courses before accessing the pre-university (or a career) science program.

latecomers struggled to identify with science, and hence I decided to make this the focus of my dissertation, extending the research to continue over another year for a total of 18 months.

Participants

A total of 25 latecomers participated in this research, seven of whom were trying to (and in some cases did) access a science-related career program such as nursing, dental hygiene, engineering technology, and radiology, rather than the pre-university science program that the other 18 were trying to access. Although I also do consider these seven students to be latecomers to science, this dissertation largely focuses on the 18 participants trying to access pre-university science. Outside of Chapter 4, references to latecomer participants refers to these 18 latecomers, unless otherwise clarified.

All 25 participants were members of the make-up physics course I taught, beginning August 2009. There were a total of 41 students in the course. The remaining members of the make-up course were exchange students and students who had recently moved from another province, both sets of whom had been taking the traditional sequence of courses for pursuing a future in science and were simply staying on track by taking the make-up course. Neither of these sets of students are considered latecomers to science in this research.

Figure 1 diagrams the sequence of courses (educational trails) that 17 of the 18 latecomer participants (trying to access pre-university science) took through high school. One latecomer, Naveen, is not included in Figure 1 because he attended high school outside of Canada.[6] These latecomers did not complete Grade 11 physics because they (a) were not in the advanced stream, (b) did not want to pursue postsecondary science, (c) thought physics was too difficult, (d) tried physics but dropped it or failed, or (e) a combination thereof.

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[6] All figures and tables are located at the end of their respective chapters.

General Methodology

In order to address the overarching goal of better understanding latecomers' persistence, this research took the form of an 18 month qualitative case study of latecomers' identification with science in the figured world of the Island College science program (Yin, 2009). An essential part of case study methodology is to provide an overall picture of the context at multiple levels. This research therefore adopts an embedded design, operating at multiple levels of analysis (Yin, 2009). Embedded design is particularly appropriate for studies in which the goal is to describe the features, context, and process of a phenomenon, such as identification with science (Yin, 2009). In this dissertation, latecomers' persistence will be explored through three approaches to understanding their identification with science, each presented in its own chapter in manuscript form (Chapters 2-4). Each chapter focuses on different scales of analysis, but importantly, all are embedded within the context of the figured world of the Island College program. Also, although the analyses presented in Chapters 2-4 also use various forms of case study design, they are only components of the overall embedded case study. Any reference to the embedded case study, or the overall research is referring to the dissertation research as a whole, rather than one of the three analyses embedded within this study.

Operationalizing Identity Work

It is difficult or perhaps impossible for researchers to capture all aspects of an individual's complex identity constructions over even a relatively short period of time. Instead, researchers must choose those aspects that are most pertinent to their study (Barton et al., 2013). Because of the multiple approaches to exploring identification taken in this study, this dissertation is able to focus on both the interactive process of positioning and recognition in relation to science and the process of making sense of experiences in science, although not always at the same time. As earlier discussed, these two aspects of identification are not theorized as separate, but as both continuously occurring, where each is an important part of the other as latecomers participate in the figured world of the Island College science program. However, different types of data more easily lend themselves to looking at one process or the other, and defining what these data are helps operationalize the complex concept of identification into something that can be observed and studied.

In this research, the interactional process of positioning and recognition is viewed as most clearly taking place through actions such as participating in class, asking questions, using lab equipment, speaking/writing back and forth with peers or other science-related people, visiting a professor outside of class, or taking a test. For example, the analysis presented in Chapter 3 uses classroom and lab observations to observe how latecomers engage in positioning and recognition in their courses and the resources they use to do so. In contrast, acts of self-authoring can be most clearly observed in participants' writings and/or longer chunks of speech in which they are reflecting on their experiences in science, although it is acknowledged that even in single sentences and fast exchanges with others, individuals can engage in self-authoring (and of course, in their thoughts, which cannot be observed). For example, the analysis presented in Chapter 2 uses reflective journal entries, online forum posts, and interview data to observe how latecomers author themselves over time and the resources they use to do so. However, the online forum data presented in Chapter 4 was analyzed in ways that gave insight into both aspects of identity work at the same time. In these reflective but interactional posts, latecomers were able to make sense of their past experiences through narration in ways that positioned them as capable of doing science, while simultaneously giving and receiving recognition to and from other participants. The main levels of analyses of identity construction (identity work in interaction, self-authoring, identity trajectories, and the constraints and affordances of the figured world of the science program) used in each chapter are diagrammed in Figure 2 and an overview of each research approach is provided at the end of this chapter. First, however, the methods used for collecting and analyzing data for this embedded case study of latecomers' identification with science are described in the following section.

Data Collection and Analysis

In keeping with the social practice theoretical framework, all data and analysis is qualitative. Data was collected over 18 months, beginning at the start of Fall semester in August 2009 and ending after Fall semester in January 2011. In order to better capture the complexity of the process of identification and persistence in science, a wide range of data types was collected (Yin, 2009). A timeline of the data collection is given in Figure 3, details of the data sources and analysis pertinent to each of the three research approaches to studying latecomers' identification with science are given in their respective chapters, and an overview is presented here.

Data collected from each participant in the first semester, during the make-up physics course for which I was the instructor, included five online forums, five reflective journals, and background data forms from which basic demographic information was obtained. Forums and journals were a mandatory part of the make-up physics course, and thus all 41 students participated. The online forums and reflective journals were designed to get students talking about their experiences in, and understandings of, science. For example, the first forum asked students, "What does science mean to you, and how do you see yourself participating in science (both now and in the future)?" For every forum, students had to respond to a minimum of two of their peers' postings as well as write an original post. The first journal asked students, "Why do you think you did you not take (or pass) Physics 11 in high school?" Students wrote a response to this prompt that was private between me and them. I responded to each journal individually, asking for elaboration or asking questions that arose naturally, where appropriate. Students then responded to my reply, and the journal entries diverged from there. The journals and forums were a mandatory part of the make-up physics course, and thus all 41 students participated. This pedagogical choice was made in light of research that has shown that opportunities for marginalized students to discuss their experiences and difficulties in science can help them better connect science with their lives (Barton, 1998).

After the make-up physics course was finished and final grades were entered, six latecomers were asked to continue to participate in the research during the next year, meaning they would continue to write journal entries, participate in interviews at the end of Winter 2010 and Fall 2010 semesters, be observed in their science courses, have their final grades collected, and have their science teachers interviewed at the end of each semester. They all agreed. These six were selected because they all expressed significant interest in the research during the first semester and all seemed likely to persist in science at least through second semester. These six were interviewed at the end of second semester, along with three other latecomers. Of the remaining nine latecomers (out of the 18 who were trying to access post-secondary science), six had already left the program and couldn't be contacted and three were unavailable for interviews.

Although a variety of data analyses were performed and are elaborated on in Chapters 2-4, the cohering form of data analysis across the embedded case study is Gee's (2011a, 2011b) critical discourse analysis (CDA). CDA is very useful for exploring processes of identification within a figured world because it focuses on connecting micro-scale language use to the social, political, and historical contexts in which the language is situated (Fairclough, 1995; Gee, 2004). Gee's CDA was selected because it provides analytic tools specific to both the construction of identity and the figured worlds within which identity is being constructed (i.e., the Identities Building Tool and the Figured Worlds Tool [Gee 2011a]). The following briefly describes the aims of each of the three embedded approaches to exploring latecomers' identification with science.

Overview of Chapters 2-4

Chapter 2 introduces latecomers to science to the science education research agenda, tracking the persistence of all 18 latecomers in their first year of the science program and exploring the trends in science identity trajectories of nine of these latecomers (described as a multiple case study in the box for Chapter 2 in Figure 3). This chapter asks the following two research questions:

1. What trends in science identity trajectories are latecomers to science able to construct during their first year in a CEGEP science program?
2. How are latecomers' identity trajectories constrained by or improvised with the cultural models and associated resources available in the figured world of a CEGEP science program?

Drawing largely from students' narrative data (i.e., journal entries, interviews, and online forums), Chapter 2 examines the cultural models made available by the figured world of the science program that the latecomers use to author themselves as moving towards or away from science, which are, in turn, understood to guide their participation in the figured world of the science program. Acknowledging the possibility for individual agency, this chapter also explores if and how latecomers can improvise ways to avoid being forced onto outbound trajectories by the dominant cultural models. This relatively large scale of analysis (e.g., looking at social structure and change in identification over scales of months rather than minutes) provides insight into how the figured world of the science program exerts forces on latecomers' science identity trajectories, constraining their ability to construct inbound trajectories and persist in the program.

Chapter 2's focus on self-authoring and students' narrations offers a useful lens into larger scale processes in which latecomers use and improvise with the available resources to make sense of their ongoing experiences and author themselves as moving towards or away from science. However, the focus on narration does not allow an exploration of how latecomers actually engage in identity work in their courses (hence *identity work in interaction* is the one level of analysis not labelled as being explored in Chapter 2 in Figure 2). To address this, Chapter 3 asks the following research question:

3. What overarching cultural models are reproduced in the courses of the figured world of the science program and how do latecomers use the resources made available in their courses to advance their identity work towards science?

Drawing from classroom and lab observations and teacher interviews, as well as journals and student interviews from second and third semesters, Chapter 3 provides a general analysis of the resources available for engaging in identity work within the courses of the science program (this design is summarized in Figure 3). Following two successful latecomers as they participate in their science courses over their second and third semesters, it is shown how they negotiate the process of positioning and recognition in interaction with their teachers. In this way, Chapter 3 explores how the figured world of the science program not only shapes how latecomers make sense of their experiences in science as was done in Chapter 2, but how these experiences unfold in social interaction. Also, the longitudinal aspect of the analysis presented in Chapter 3 allows an examination of how repeated identity constructions in interaction can impart momentum to latecomers' trajectories over time. In this way, the micro-scale analysis of identity construction in interaction is tied back to the larger question of persistence (hence Figure 2 labels Chapter 3 as providing analysis of identity work in interaction, identity trajectories, and the figured world of the science program).

Chapter 2 and Chapter 3 focus on the resources made available by the figured world of the science program. In contrast, Chapter 4 focuses on latecomers' co-construction of new resources to afford identification with science, asking the question:

4. How do latecomers with histories of being recognized as not smart enough to do science, use resources to identify with science in an online forum?

Drawing from the five online forums conducted in the first semester, Chapter 4 (described as a single-case study in Figure 3) analyzes one thread in which four latecomers co-construct new resources to make sense of their histories of disidentification with science and help them identify with science in the present. In this way, this third and final embedded approach to exploring latecomers' identification with science, adds one more dimension to the overall case study: the possibility of liberation from some of the constraints of the figured world of the science program via agency. Despite its smaller scale focus, Chapter 4 still examines the constraints of the figured world within which participants must improvise, thus also contributing to an increasing understanding of the figured world of the science program (hence in Figure 2, Chapter 4 is labelled as providing analysis of identity work in interaction, self-authoring, and the figured world of the science program).

Figure 1: Educational trails of 17 latecomers in high school.
Underlined latecomers switched into the preparatory program from another postsecondary program. The rest entered directly from high school or after taking adult education courses. Bolded latecomers participated in first round of student interviews (see Figure 2). Numbers in parentheses correspond to those used in Figure 2 to show which students participated in the various types of data collection. Latecomer #6 (not shown) attended high school outside of Canada.

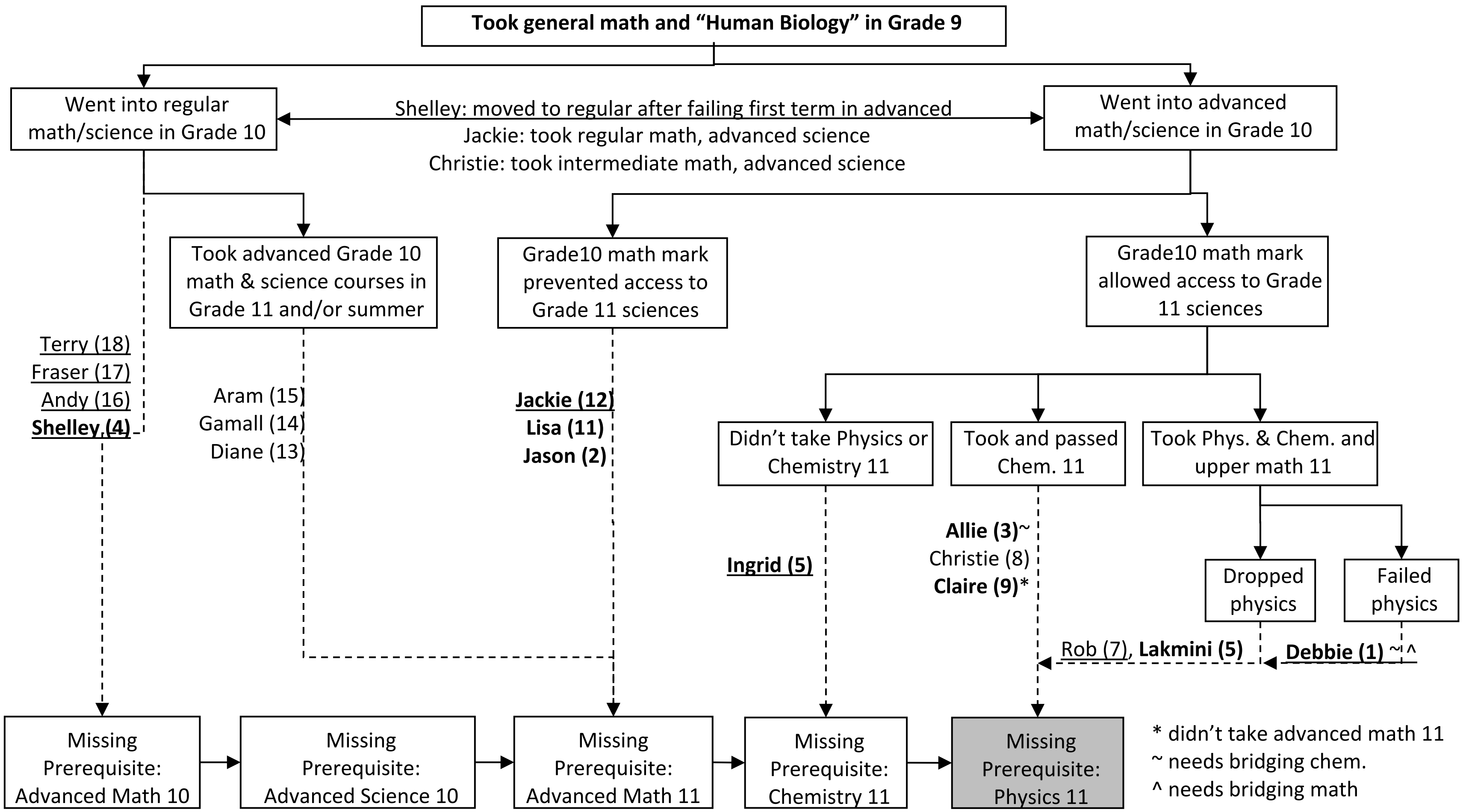


Figure 2: Contributions of three chapters (Ch.2, Ch.3, Ch.4) to the overall case study.
Each nested box represents a smaller scale of analysis of the process of identification with science, where identity work in interaction is the smallest scale studied. The dotted lines are reminders that the processes are not discrete, but instead they all are a part of each other. For example, one's identity work in interaction with others is made sense of through the self-authoring process, is the next *data point* (Jackson & Seiler, 2013) in one's shifting identity trajectory, and (re)produces the figured world of the science program. Vice versa, one's identity work in interaction is guided by how one learns to makes sense of one's experiences and participation, which is part of the momentum of one's identity trajectory, and is constrained and afforded by the figured world of the science program.

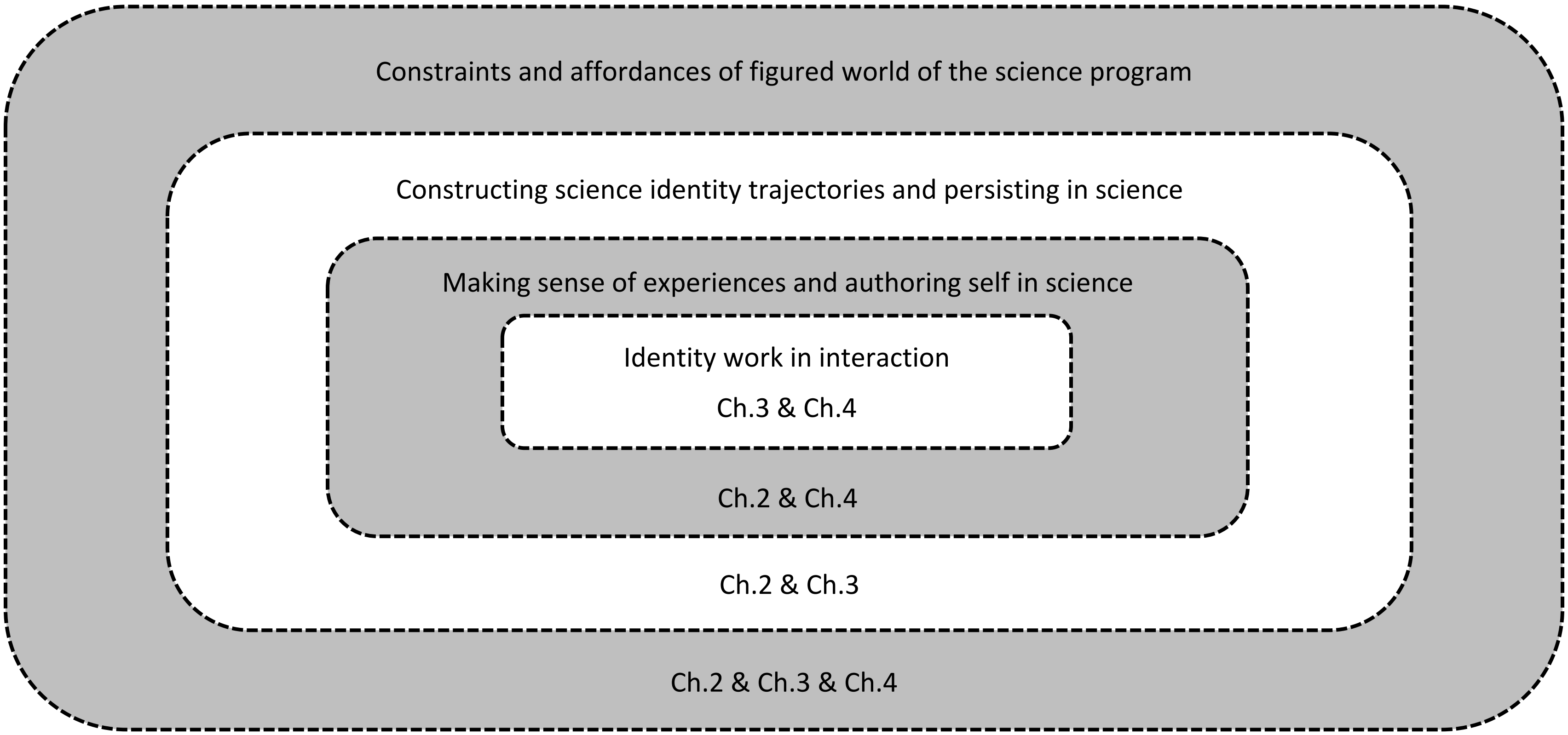
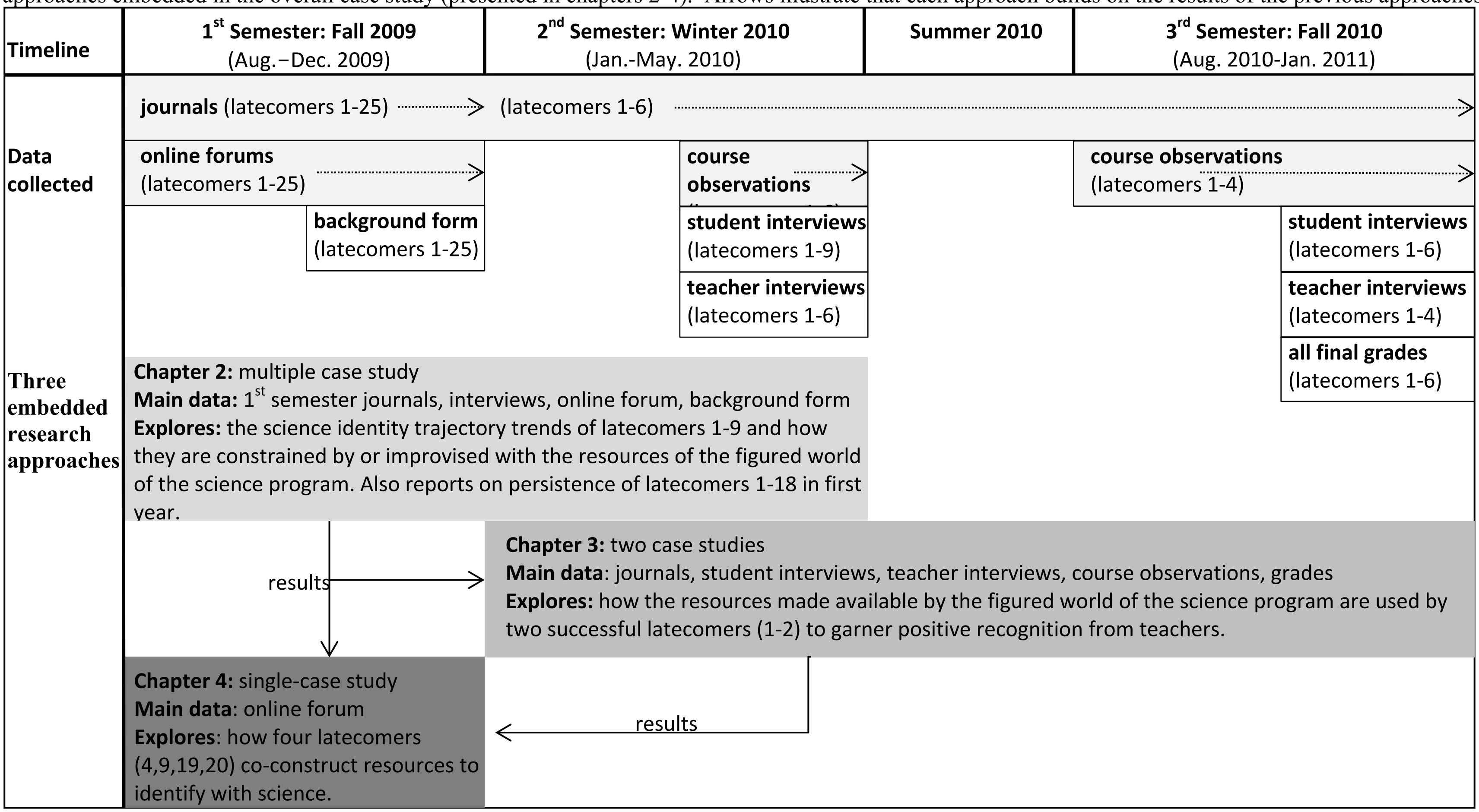


Figure 3: Timeline of 18-month research design.
Of the 25 latecomer participants, 1-18 were entering science program and 19-25 were entering science-related career programs. Latecomers 1-6 were followed for entire 18 months but of these six, only latecomers 1-4 persisted into and through 3rd semester and only 1-3 to graduation. Lightly shaded data boxes signify data collection that carried over a month or more as opposed to single events such as interviews. The three darker boxes at the bottom summarize the research approaches embedded in the overall case study (presented in chapters 2-4). Arrows illustrate that each approach builds on the results of the previous approaches.



Chapter 2: Science Identity Trajectories of Latecomers to Science in College

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Abstract

This study introduces a new group of students to the postsecondary science agenda: *latecomers to science*. Latecomers, who enter postsecondary science through alternative routes because they are missing prerequisites, are less likely to graduate than traditional science students. Challenges to latecomers' persistence are explored through two questions: 1) What trends in science identity trajectories are latecomers to science able to construct during their first year in a college science program? 2) How are latecomers' identity trajectories constrained by or improvised with the cultural models and associated resources available in the figured world of a college science program? These questions are investigated through an analysis of educational activities, reflective writings, and interviews of nine latecomers. We view identification as analogous to velocity and demonstrate how recurring forces exerted by figured worlds and cultural models within them create patterns of acceleration towards or away from science, thus supporting or hindering persistence as identity trajectories gain or lose momentum. Findings show that latecomers' persistence was greatly constrained by two cultural models from the science program: good science students follow a paradigmatic sequence of courses and consistently earn good grades. Occasionally, latecomers improvised to resist these constraints. We illustrate our findings through three cases exemplifying inbound, outbound, and peripheral trends, offering a method of representing trajectories that may lead to new understandings of persistence. We also suggest implications for better supporting latecomers and connect this

research to recent developments in the theoretical and methodological use of identity trajectories in understanding access to science.

The global phenomenon of youths' decreasing engagement in science has caused governments and researchers to intensify efforts to widen the pool of students entering and persisting in postsecondary science. However, one group continues to be overlooked: students who enter through alternative routes rather than directly from high school (Mueller, 2008). We term these students *latecomers to science*. Latecomers differ from traditional science students in that, prior to university, they often follow a sequence of courses that is different from that of traditional science students and often have a history of mixed academic achievement, meaning they have received some low or failing grades in science. Both of these differences have been found to correlate with reduced persistence in postsecondary science (American College Testing, 2006; Chen & Weko, 2009). Research is therefore needed to explore their complex educational paths to learn how to best support their persistence. Accordingly, this study seeks to better understand the persistence of latecomers through a qualitative exploration of the science identity trajectories of nine latecomers to science at Island College, an Anglophone Québec Collège d'Enseignement Général et Professionnel (CEGEP).[7]

CEGEPs are public colleges that provide two-year pre-university programs, three-year career programs, and technical programs.[8] In Québec, secondary school ends after Grade 11, after which students can attend CEGEP. The two-year CEGEP pre-university science program is

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[7] A pseudonym is used for the CEGEP.

[8] Québec's tuition free colleges provide a unique opportunity for research into factors contributing to student enrollment and persistence in postsecondary science without the obscuring influence of tuition fees.

comparable to 12th grade and first year university in the rest of North America. In Québec high schools, students are streamed into advanced or regular science and math courses in Grade 10 depending on their marks.[9] To access a pre-university science program directly, students must earn at least 70% in the Grade 11 advanced math and science courses. If students are missing prerequisites, they may access the CEGEP *preparatory science program*, in which they have two semesters to complete make-up courses. If successful they will be accepted into the pre-university science program. These are the students we call latecomers to science. Note that, when we refer to the "science program," we are actually referring to two consecutive programs at Island College: the science preparatory program and the pre-university science program, the former of which is intended to feed directly into the latter.

There is a significant amount of research on persistence in the science *pipeline*. Much of this research focuses on understanding attrition, viewed as leaks in the pipeline, occurring near the end of high school into and through undergraduate degrees (e.g., Chen & Weko, 2009; Maltese & Tai, 2011). Although such studies tend to take a quantitative approach, gaining a broad view of the pipeline, some studies have used ethnographic methods to explore the experiences of individual students, thus providing deeper insight into the processes underlying students' persistence (e.g., Seymour & Hewitt, 1997; Tobias, 1990). Recent research has critiqued the current pipeline paradigm's inability to address the complexity of science students' enrollment and persistence (e.g., Aschbacher et al., 2010; Hanson et al., 1996). Xie and Killewald (2012) called attention to the pipeline's failure to account for students who switch into science from non-science degrees. We recognize a similar oversight of students who are unable to access postsecondary science directly out of high school. By introducing *latecomers to science*

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[9] This process has changed slightly now, but it applied for the participants in this study.

to the research agenda, we highlight the need for pipeline research to address the increasingly complex educational pathways that students are following (Finnie & Qiu, 2008; Xie & Killewald, 2012).

Our emphasis on persistence in science is reflective of the participants' expressed desire to pursue a future in science, also evidenced by their entry into the science preparatory program and the sacrifices they made to access science (e.g., time, money, and effort). It does not indicate our allegiance to the notion that science is the best option for every student nor that it is superior to other fields of study.

Theoretical Framework

This study recognizes that identities are constructed through participation in the social sphere as people position themselves, or are positioned by others, and make sense of this positioning in the moment and over time. The Island College science program is situated within multiple social worlds, which latecomers negotiate as they make their way into and through the science program. Accordingly this research is framed around Holland, Lachicotte, Skinner and Cain's (1998) theory of identity-in-practice and their concept of figured world, as well as an adaptation of Etienne Wenger's (1998) identity trajectories. This work builds on that of others who have used these ideas in science education (e.g., Johnson et al., 2011; Tan & Barton, 2008a, 2008b), as we apply these ideas to a particular set of students, with particular attention to the institutional structures that shaped students' identity construction over time. As in Johnson et al.'s (2011) study of women of color in science, we are interested in how the latecomers authored their identities, the social and institutional structures that constrained and afforded these authorings, and how their authoring of identities changed over time.

Identity, Figured Worlds, and Cultural Models

Our interest in the interplay between social and institutional forces and possibilities for individual actions leads us to recognize that production and reproduction of social worlds both fuel and are fueled by identity construction. Drawing from and responding to available resources, actors participate in certain ways to take up available subject positions, bidding for recognition as certain types of people, such as members of a particular community (Gee, 2000). Thus, identity is shaped by the resources, including the positions available for use by actors, how others recognize and respond to such bids, how actors respond to ascribed subject positions, as well as the figurings and meanings that actors construct of their actions, interactions, positionings, and recognitions. Describing this process as a layering of identity, Wenger (1998) noted that this "interweaving of participative experience and reificative projections" (p. 151) and the negotiation of meaning around them are key to constructing who we are.

In combination with identity, we use the concept of figured world because it provides a way to examine the interplay between individual actions and structures and to attempt to understand the "matrix of oppression" (Johnson et al., 2011, p. 343) that can exist within a social realm. Figured worlds have been operationalized in a number of ways in educational studies. Urietta (2007) noted that this multiplicity mirrors "the complexity of social/cultural life itself and the people who participate in it and how they make sense of themselves and their participation" (p.112). Like Urietta, we see the versatility of figured worlds as an advantage in that it can be applied in a variety of ways and at a variety of grain sizes.

Though many in science education have employed identity as a lens through which to explore access to science education at all levels, fewer have applied the concept of figured worlds to such questions. Tan and Barton (2008b, 2010) conceptualized classrooms as multiple figured worlds and explored them as spaces shaped by teachers and students that can offer diverse possibilities for students to author their identities. Similarly, Jurow (2005) represented a middle school design project as a figured world that offered multiple roles for participation. In higher education, there are two notable uses of figured worlds. Tonso's analysis (2006) drew attention to a campus engineering community as a figured world and documented powerful cultural forms of scientist and engineer that permeated that world. Although not focused on science, the usage of figured worlds by Hungerford-Kresser and Vetter (2012) is most similar to ours. Their study described the identity negotiations of a Latino student at university, documenting how, in the figured world of the university, "discourses function as powerful, non-neutral positioning tools that sort students" (p. 223).

A figured world is a set of simplified stories, or a "realm of interpretation" (Holland et al., 1998, p. 52) that capture what is taken to be typical in a given context (e.g., the Island College science program). Through participation in activities organized by a particular figured world, actors learn meanings of forms of participation, storylines, and subject positions. Figured worlds value some forms of participation over others (Holland et al., 1998), meaning that certain subject positions are associated with success and increasing participation (e.g., a good science student) and tend to lead to positive recognition by meaningful others (e.g., teachers and administrators).

Figured worlds rely on cultural models that "consist of schemas (mental/emotional knowledge structures) that guide attention to, draw inferences about, and evaluate experience" (Holland et al., 1998, p. 297). Cultural models are supported by a situated "system of artifacts" (Holland et al., 1998, p. 127) including material objects, texts, media, and language. Thus, both models and artifacts, as well as the storylines and subject positions that they make available, serve as resources that construct a wide or narrow range of possibilities for participation in a figured world.

Despite the limiting and constraining actions of cultural models, there is the possibility of resources being used in ways that can liberate participants from the constraints, a process that we, like Holland et al. (1998), refer to as improvisation. They explain, “The constraints are overpowering, yet not hermetically sealed” (p.18). One can acquire new resources or use resources in novel ways or in new contexts, which can afford greater participation in a particular figured world and shape one’s identity construction. This is referred to as “leveraging resources” and “strategic deployment of resources” by Basu, Barton, Clairmont and Locke (2009, p. 355). In our study, locating the cultural models and associated resources that populate the Island College science program allows us not only to understand how figured worlds can impede latecomers’ persistence, but also how latecomers can, and do, resist those structures of privilege and marginalization.

Figured worlds exist on multiple scales, including historical, global and local. Localized processes make possible the patterns of larger processes that, in turn, shape what is likely and appropriate on smaller scales (Lemke, 2000). In this paper we focus on the figured world and the associated cultural models of the Island College science program. This grain size is chosen to match our interest in persistence in the science program. However, we will illustrate that this figured world is “nested in larger social contexts that are inextricably connected to one another” (Reveles et al., 2004, p. 1112); in a few instances we will show that the figured world of the science program is connected with wider figured worlds, such as those of the Québec education system and the figured world of science.

For actors, “cultural models also provide a framework for organizing and reconstructing memories of experience” (Holland et al., 1998, p. 297). Thus, we can understand figured worlds and how their cultural models constrain and afford participation by exploring how people understand themselves or *figure* who they are in relation to the world (Rahm, 2012; Urrieta, 2007). We consider all narratives, including those about the past, not as factual accounts, but rather as retellings and reinterpretations of events and identity formations. The data used in this research, such as interviews and reflective writing, provide a window into such figurings, while the longitudinal nature of the study provides insights into how such figurings changed during the study year and how the figured world of the science program shaped those changes. As well as the term *figuring*, we also use the term *authoring* for this process of reinterpretation and representation because, as Rahm explained, “authoring underlines the active re-constructive process” (Rahm, 2007, p. 521).

Identity Trajectories

Our interest in persistence compels us to consider how identification with science changes, or doesn’t change, over time. Johnson et al. (2011) were also concerned with science identities and “ways in which those processes were stable and/or changed over time” (p.342). Varelas, House and Wenzel (2005) noted the need to pay attention both to “short timescales of a certain situated activity and larger timescales that span across recurring similar activities” (p. 495). But this is no easy task, as Barton et al. (2013) noted in their study of girls’ participation in science.

In paying attention to changes over time, we view identity construction as a continuous *process* of identification, and thus we liken identification to *motion* rather than a certain location or distance from science at a point in time. By viewing identity as a motion instead of a “static noun" (C. Brandt, 2008, p. 706), we aim to better understand how identification or disidentification moves one towards or away from ideas and practices of particular groups This leads us to conceptualize identification as akin to a *velocity* vector, which describes the speed and direction of motion at a specific moment. We visualize that an individual's identification with science is analogous to his or her motion in relation to science at any moment, where stronger/weaker identification with science is analogous to faster/slower motion towards science, and stronger/weaker disidentification with science is analogous to faster/slower motion away from science. Extending this over time, identification with science can be visualized as a series of motions relative to science. Conceptualizing identification as velocity allows us to visualize science identity trajectories in a particular way, which we will show, has theoretical and methodological strengths.

Researchers can never know the countless moments of identity construction during the span of a year or a semester. Yet, the consequences of this process across time and space is profound (Rahm & Ash, 2008). We can, however, recognize general patterns of identity construction over time, and we conceptualize this using *identity trajectories* (Gee, 2000; Johnson, 2012; Wenger, 1998). A science identity trajectory is an individual's unique sequence of science-related identity constructions and is representational of the "psychosocial formations that develop over a person's lifetime" (Holland et al., 1998, p. 5). Although we use a graphical representation to visualize identity trajectories and to highlight certain aspects of them, as described below, we are not claiming that identity is quantifiable or linear.

The concept of an identity trajectory recognizes that identities form, shift, and transform as a participant moves across space and time. Like Holland et al. (1998), we acknowledge that identity trajectories do not take a direct path. Rather, we envision a science identity trajectory as a *curve of best fit* drawn through a scatterplot (see magnified view in Figure 1) of one's science identity constructions (velocities) vs. time. Such a curve shows the overall trends in the points on a scatterplot, namely, regions of increasing, decreasing, or unchanging identification with science over time. These trajectory trends appear as positive, negative, or zero slopes on an identity vs. time graph such as Figure 1, or extending our analogy, as regions of acceleration towards science, acceleration away from science, or no acceleration. Similarly, a steeper slope corresponds to greater change in identification over time, or greater acceleration towards or away from science.

Because we are interested in the trajectories of people who, prior to this study, had difficulty identifying with postsecondary science, we are most interested in change in identification, that is, the *acceleration* of one's identification with science over time. In order to accelerate something's velocity (speed up, slow down, and/or change direction), a net *force* must be applied; likewise in identification with science. The concept of forces shaping one's identification over time is not new. Wenger (1998) referred to a "field of influences" (p. 154) that acts on one's identity trajectory. Barton et al. (2013) elaborated on what such a field of influence consists of: "As individuals move through the world—through time and space, such as through middle school science—they are exposed to, positioned by, and react to a range of people as well as institutional and cultural structures and forces" (p. 41). Because we are most interested in the larger forces that persist over time to accelerate latecomers' trajectories, we conceptualize the dominant cultural models and the associated resources that comprise a figured world, such as that of the Island College science program, as exerting forces on an individual's identity trajectory, thus accelerating them towards or away from science. We do not consider figured worlds, cultural models, or resources in and of themselves to be forces. Rather, they may exert forces of a particular strength in a particular direction when used in a certain way by the actors.

The construction of an identity trajectory is a continual process of negotiation and recognition in which one acquires and uses resources that can assist or hinder in future instances of identity construction. What happens at one moment of identity work, therefore, shapes future identity work. Johnson et al. (2011) elaborated on this aspect of identity trajectories, saying, “We assume that their identities reflect relatively patterned, ongoing conceptions of themselves” (p. 345). We use the concept of *momentum* to describe this buildup of resources that creates a patterning or thickening of identity (Holland & Lave, 2001). We contend that, as one builds up resources, it becomes increasingly easier or harder to identify with science. This accumulation of resources, conceptualized as momentum and, thus, proportional to velocity (identification), can keep a trajectory moving towards or away from science, often sweeping someone along, making it difficult to shift trajectory trends when momentum is great (Wenger, 1998).

Consider this example of how momentum is tied to recognition and the thickening of identity. Two students in the same class both forget their homework. One has a history of being positioned as a good science student, the other as a slacker. The former student is able to laugh it off with her teacher, thereby being positioned, once again, as a good science student (continuing to move towards science). Conversely, the other student is likely to be admonished, thus being again positioned as a slacker (continuing to move away from science). In understanding such occurrences, we connect momentum to Holland et al.’s (1998) history-in-person: “One’s history-in-person is the sediment from past experiences upon which one improvises, using the cultural resources available, in response to the subject positions afforded one in the present” (p. 18). In this way, the gaining of momentum, due to ongoing accumulation of resources and recognition, may keep one moving towards or away from science, but may also interfere with efforts to shift one's trajectory.

Identity trajectory trends. To describe identity trajectories, we modified three of Wenger's (1998) categorizations: inbound, outbound, and peripheral. These trajectory trends are illustrated in Figure 1, which shows some of the many possible trajectories that a hypothetical latecomer to science might construct during her first year in CEGEP science. Note that, in Figure 1, the starting point of the hypothetical trajectories is slightly above zero, indicating that the latecomer is initially moving towards science at a relatively low velocity, but is above the dividing line between identification and disidentification with science. This indicates that, at the start of the year, she tends to be able to identify with science, but not very strongly, as was the case for most latecomers to science just beginning their foray into postsecondary science.

Inbound science identity trajectories are characterized by *increasing* identification with science over time (acceleration towards science). As an individual experiences successful efforts to identify with science, he or she comes to acquire and embody resources that can help future identity negotiations, hence building the trajectory's momentum towards science. If maintained, an inbound trajectory will result in graduation from a pre-university college science program followed by entrance into a science-related university program. Accordingly, the inbound trajectory is viewed as the most desirable in the context of latecomers attempting to gain access to science. Trajectory A in Figure 1 illustrates a simple inbound trajectory that a hypothetical latecomer to science might construct if she experiences increasing success identifying with science during her first year in CEGEP science. As with all inbound trajectories, the slope of her trajectory is positive, indicating *increasing* identification with, or acceleration towards, science and thus the gaining of momentum towards science over time. As a side note, Trajectory A's slope becomes less steep with time, indicating that while the hypothetical latecomer's velocity towards science is always increasing (i.e., she is accelerating towards science), there is greater change in the beginning of the year and less change as the year progresses.

Although many other shapes of inbound trajectories are possible, it is worth considering that, if continued as shown, Trajectory A would approach a flat line, meaning the hypothetical latecomer would be moving at a constant, fast velocity towards science (no acceleration). In other words, in such a scenario, she reaches a time when she is consistently able to identify strongly with science. We theorize such a trajectory trend to be what Wenger (1998) refers to as an *insider* trajectory. Due to its consistently fast motion towards science, such a trajectory would have a very large momentum, and thus would be very difficult to shift away from science. We mention this to paint a full picture of identity trajectories, but insider trajectories are not relevant to the situation of latecomers to science in their first year of college science, and so they are neither shown in Figure 1 nor elaborated on further.

Outbound science identity trajectories are characterized by *decreasing* identification with science (accelerating away from science). As an individual experiences unsuccessful efforts to identify with science, he or she comes to acquire and embody resources that can hinder future identity negotiations, hence building the trajectory's momentum away from science. Ultimately students who remain on an outbound trajectory are likely to stop participating in school science. Trajectory D in Figure 1 illustrates an outbound trajectory that a hypothetical latecomer to science might construct if she experiences many instances of failure during the beginning of her first year. Again, there are many shapes an outbound trajectory may take. However, in this case, we have chosen to illustrate that, due to her decreasing ability to identify with science, she leaves the program early in the year (around time t_1), and thus, having lost her ability to draw on her status as a science student as a resource for identification with science, she accelerates even more quickly away from science. Soon her trajectory enters the shaded half of the graph in Figure 1, which encompasses all velocities less than zero, hence indicating an overall pattern of disidentification with science (e.g., motion away from science).

A *peripheral science identity trajectory* is characterized by identification that remains near the dividing line between identification and disidentification with school science (no acceleration, slow velocity). If a student experiences mixed success identifying with science, the general trajectory trend may be neither increasing nor decreasing. Trajectory C in Figure 1 illustrates a peripheral trajectory that a hypothetical latecomer to science might construct if she experiences roughly equal amount of success and failure identifying with science during her first year. Importantly, we are not claiming that her identification remains constant, rather, that it repeatedly fluctuates between identification and disidentification. Although at any given moment she may be moving towards or away from science, her overall pattern of identification with science is unchanging, moving at a constant slow speed towards science (velocity just above zero). This means that her trajectory has little momentum to sustain her through any periods of difficulty identifying with science, and she remains precariously on the margins of school science until a net force (e.g., institutional constraints or individual agency) accelerates it, constructing a new trend.

Inbound, outbound, and peripheral, are the three trajectory trends that could possibly be constructed as latecomers attempt to gain access to school science, successfully or otherwise, during their first year. However, we expect that not all latecomers will have single-trend trajectories during their first year, and hence Trajectory B in Figure 1 illustrates one of the many possible shifts in trajectory that a hypothetical latecomer might experience. This shift was not selected arbitrarily, but in light of our findings detailed later, in which shifts in trajectory trends always occurred in the negative direction. In Trajectory B, the hypothetical student is first increasingly successful at identifying with science (inbound trajectory), and as her motion towards science increases in speed, she gains momentum. At time t_2, she encounters a challenge to her continued identification with science. Her previously gained momentum helps her to continue moving towards science for a while (i.e., Trajectory B remains in the upper, unshaded half of the graph for a while), but her motion slows as she loses some of the resources that helped her identify with science and acquires other resources that hinder her identification. Eventually she disidentifies more often than she identifies with science, thus moving away from science (i.e., Trajectory B enters the shaded area) and picking up momentum away from science. Her decreasing ability to identify with science, that is, her outbound trajectory, is indicated by the negative slope of her trajectory from time t_2, onwards. Importantly, a shift as abrupt as this one would require a relatively strong net force in the negative direction (away from science). For example, in a case presented later in this paper, a push having a similar effect arose from the conflict between the dominant cultural models of the science program and the latecomer's family responsibilities.

While we acknowledge that trajectories extend beyond any specific time frame, our focus in this paper is on latecomers' trajectories during their first year in the Island College science program and how the local cultural models, which also intersect with wider models, shaped their identity construction.

Methodology

Given our interest in better understanding latecomers' persistence in science as well as the role of the figured world of the science program in organizing the activities through and in which identities are formed, we posed the following research questions:

1. What trends in science identity trajectories are latecomers to science able to construct during their first year in a CEGEP science program?
2. How are latecomers' identity trajectories constrained by or improvised with the cultural models and associated resources available in the figured world of a CEGEP science program?

Participants

All participants were members of a make-up physics course taught by the first author at Island College in the fall semester, 2009.[10] The course consisted of 41 students, 18 of whom were latecomers to science trying to access the pre-university science program. The remaining students were either exchange students in their final year of high school back home or Québec students trying to access career programs, such as dental hygiene. Because neither of these sets of students was trying to access a postsecondary science program, we did not consider them latecomers to science. The 18 latecomers did not complete Grade 11 physics because they (a) were not in the advanced stream, (b) did not want to pursue postsecondary science, (c) thought physics was too difficult, (d) tried physics but dropped it or failed, or (e) a combination thereof. All teaching and data collection were conducted in English.

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[10] For ethical reasons, consenting students were unknown until final grades were submitted.

Data Collection

A wide variety of data sources, collected over two semesters, were used to envision the latecomers' educational trails and identity trajectories. A student background form provided basic demographic information such as age, gender, country of origin, generation of immigration, reason for taking make-up physics, missing high school prerequisites, and a description of high school science grades. Online journal entries and discussion forums, which were course requirements, are described below. CEGEP grades and enrolment records were accessed for all 18 latecomers, and one end-of-year, semi-structured audio-recorded interview was conducted with nine participants in the study.[11]

During the first semester all students wrote reflective journals every three weeks, totaling five during the 15-week course. The first topic was intended to stimulate consideration of past science experiences: Why do you think you did not take (or pass) Physics 11 in high school? Only the course instructor (first author) read these, individually responding to each entry, which ranged in length from a few sentences to a full page. Students used the instructor's responses as a prompt for subsequent entries. All members of the course also participated in five online forums during the first semester where they discussed their experiences in science with each other (see Table S1 for forum topics). Participants were required to post one original message per forum and respond to at least two of their peers' postings. All online text was downloaded and the interviews were transcribed for analysis.

Data Analysis

Taking a multiple case study approach (Yin, 2009), the persistence of all 18 was followed

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[11] This study is part of a larger study in in which the researcher continued to follow some latecomers in their second year of CEGEP, including in-class observations and focus groups.

during their first year at Island College using enrollment records, and from these 18, nine were selected because they remained enrolled in the science preparatory or science program during the second semester and agreed to participate in an interview. To begin our analysis, we organized the data into two sets of mutually supportive structures: educational trails and narrative data tables, as described below.

Educational trails. An educational trail is the sequence of science-related activities, courses, or programs over a specific time in an individual's life. We constructed an educational trail for each latecomer by mapping events and decisions related to school science from Grade 9 until the end of their first year at Island College (e.g., Figure S1). This was done in two parts: high school, using the background data forms; and CEGEP, using information from enrollment status and grades. In a few instances, factual information was obtained from the narrative data to fill gaps. Constructed in this way, the trails illustrated increasing or decreasing participation in school science based only on information such as courses taken, failed and passed; decisions made; programs applied to; and institutional actions. The educational trails provided some evidence of the latecomers' increasing, decreasing, or unchanging relationship with science, but also provided a background against which we could better understand the situated meanings of the latecomers' narratives. Thus, the educational trail, while not the same as an identity trajectory, was used as a starting point to characterize each latecomer's trajectory, as described further on.

Narrative data tables. For each of the nine students, all journals, forum entries, and interviews were transcribed and divided into discrete chunks, where each chunk indicated a shift in topic or point of view (Labov & Fenshel, 1977). We then developed three categories that represented recurring themes in the ways that nearly all latecomers authored their relationship with science: (a) *Stories of recognition,* which included their narrations of past experiences in which they were recognized (or not) as moving towards science, (b) *Connecting science to my life*, which included participants' narrations of science as connected to their lives in the present (e.g., how science meshed with their interests/worldview, why they liked science, or personal characteristics that made them a science person); and (c) *Projecting my future*, which included participants' narrations of their future in relation to science careers, the courses they wanted to take next semester, or a test coming up. For each participant, we arranged the chunks under each category in chronological order according to when the statements were made, regardless of when the described events happened. This resulted in nine tables composed of three columns and many rows which showed, from top to bottom, changes over time (acceleration) in participants' identification with science, and from left to right, how participants narrated the past, present, and future of their identity trajectories. Tables 2, 3, and 4 are shorter versions of these tables, showing only six rows, whereas the full data tables represented at least 21 different points in time over the year (five journals, five forums each with three or more postings, and one interview). The full tables were used along with the educational trails to explore the research questions.

Categorizing identity trajectories. Each latecomer's identity trajectory was categorized by layering their narrative accounts on top of their educational trails at various times during their first year at Island College. The dual chronological ordering of the narrative data allowed us to observe change with respect to two timeframes: during the two semesters of the study; and the past, present and future sense-making that the latecomers themselves engaged in. This allowed us to account for the complex temporal nature of identity trajectories and our conceptualization of identification as motion. In doing so, we considered the participants' narratives as "imaginative refigurings" (Holland et al., 1998, p. 141) of their past, present, and future. We were less interested in the content, that is, the details of events in their narratives, and more interested in what they chose to talk about, how they made sense of it, how they authored themselves, and, most importantly, how these tellings changed over the year at Island College. By analyzing each column from top to bottom we could observe if/how these imaginative refigurings changed, discerning patterns of increasing (acceleration towards science), decreasing (acceleration away from science), or unchanging (no acceleration) identification with science, which respectively evidenced inbound, outbound, or peripheral trajectories.

To categorize the trend in participants' trajectories when they entered the preparatory program, we observed how their participation in science had changed, or not, over the preceding few years by viewing their educational trails from Grade 9 until they entered the program. We also compared how, in their narratives about science experiences prior to accessing the program, they positioned their past selves in relation to science (regardless of when they were written/spoken) to how they authored themselves in relation to science at the very beginning of the program. For example, an educational trail showing participation in the advanced stream throughout high school, failing physics in Grade 11, and then accessing the preparatory rather than the pre-university science program suggests an outbound trajectory at the start of the study year. If the data showed this student narrating herself as wanting to be a scientist when she was in high school, but authoring herself at the very start of the study year as uncertain of whether she belonged in science, we could confidently locate her on an outbound trajectory at the start of the study year, accelerating away from science. In contrast, if the data showed this student authoring herself at the start of the year as certain she wanted to be a scientist, and making sense of her grade 11 failure and current enrolment in the preparatory program in ways that still projected a future in science, then we would locate her on an inbound trajectory, although one whose slope is becoming less steep and may be in danger, given continued experiences of failure, of shifting to outbound.

To categorize trends in participants' trajectories over the two semesters of the study year, we drew on their educational trails during the year, while also observing how their authoring of self in relation to science *changed* as they participated in the figured world of the science program. To observe the direction of change, we analyzed each narrative data table using Gee's (2011a) toolkit. Drawing on Gee's identities building tool, we asked, for each chunk, what subject position does the latecomer author for her/himself? By conducting this analysis on the table data spanning each students' first semester (journal and forum data from Aug.-Dec. 2009), we were able to observe changes in their ability to author themselves as moving towards science during that first semester. Similarly, we categorized their trajectory during the second semester, by comparing their success at authoring their identification with science at the end of their first semester and in the end of year interviews (Dec. 2009-May 2010). Note that reading across the rows allowed us to see consistencies or fluctuations in how students authored themselves at similar points in time, while reading down the columns allowed us to see changes in self-authorings, that is, acceleration towards or away from science, over longer periods of time.

Identifying cultural models. In answering our second research question, we attempted to look "into the world to grasp the person as a participant in that world" (Dreier, 1999, p. 29). To accomplish this, we returned to each participant's data table and applied Gee's (2011a) figured world tool to every narrative chunk, asking: What must the author have assumed to be normal about the world in order to have written or spoken this way? By focusing on what the participants assumed to be normal in their stories of recognition, their ways of connecting science to their lives, and their projections of a future in science, we gained insights into the cultural models that shaped their self-authorings, thus exerting constraining or affording forces on their science identity trajectories.

Two cultural models within the science program emerged as the most relevant to the latecomers' ability to construct their science identity trajectories. To further our understanding of how latecomers' identity trajectories were both constrained and afforded by these dominant models, we conducted an analysis of artifacts of the science program that reified and reproduced these models (e.g., website, rules, and terminology). Then, returning to the narratives, we looked for ways that participants were afforded or constrained by these dominant models as well as how they resisted the constraints through improvisations in which they used the models or other resources from the program in novel ways or drew upon resources from other contexts to author their science selves.

Findings

One year after entering the preparatory science program, only 8 of the 18 latecomers were still enrolled in science (and were all now in the pre-university science program), a persistence rate of only 44%, compared to the standard first year persistence rate of 72% for traditional, academically strong students who enter Anglophone CEGEPs directly from high school (Rosenfield et al., 2005). Table 1 summarizes the identity trajectories of the nine latecomers who participated in second semester interviews, (five of whom were among the eight persisters mentioned above). Of the nine, only two were able to maintain inbound trajectories during their first year. The remainder tended to shift to peripheral and outbound trends. The finding that trajectory shifts only occurred in the outwards direction (i.e. inbound→peripheral→outbound) suggests that once in the science program it is very difficult to construct an inbound trajectory, unless one already has inbound momentum. Another important finding is that not all students entered the program on inbound trajectories, suggesting that the recognition associated with being accepted into the preparatory program is insufficient to support inbound trajectories.

The Figured World of the Science Program

Two cultural models of the figured world of the science program dominated how the latecomers authored themselves in relation to science and at times afforded, but more often constrained, their ability to identify with science: (1) a good science student follows a specific educational trail and (2) a good science student gets good grades. Together these cultural models produce a very narrow and restrictive range of possibilities for identifying with and being recognized in science. These cultural models are described below, along with a brief description of the artifacts that support their reproduction.

The paradigmatic trail. Selves tend to be authored against a paradigmatic model that shows how one is expected to negotiate one's trajectory (Wenger, 1998). This is apparent in the broader figured world of education, which promotes the idea that school should be completed in a timely manner; therefore, direct routes are better than indirect routes (Mueller, 2008). This model persists despite the increasing number of students moving in and out of programs and institutions before attaining a degree (Goldrick-Rab, Carter, & Wagner, 2007).

In CEGEP, traditional science students enter the pre-university science program directly from the high school advanced stream and then follow a four-semester schedule. After graduating in two years, they enroll in a university science program and then proceed to a career in science. In the figured world of the Island College science program, this sequence, which we refer to as the *paradigmatic trail*, was communicated to participants through a system of artifacts. For example, the program's expected sequence of courses is posted online and mailed to new students. A less official but powerful convention is the terminology surrounding the paradigmatic trail, even before arriving in CEGEP. For example, in high school, students were placed into two streams. Only those students in the *advanced* stream, unofficially referred to as either the *upper* or *science* stream, graduate with the prerequisites for CEGEP science. The *regular* stream, from which the majority of latecomers came, was referred to as the *lower* or *social science* stream. Thus, the valuing of one stream and its members over another begins in high school, illustrating the intersectionality and power of cultural models across figured worlds. Similarly, in the college science program, courses offered in semesters that don't match the two-year sequence are informally referred to by teachers as *off-semester* courses. Associated with this terminology is the assumption that students in off-semester courses are academically weaker, and therefore the classes are generally less desired by teachers and are expected to have a lower class average. Such terminology instantiated and reproduced a world that figures students with educational trails that differ from the paradigmatic trail in opposition to the subject position of a good science student, making it difficult for them to be recognized by self and others as legitimate.

Good grades. In the broader figured world of education, good grades are usually equated with the possession of a stable, trait-like characteristic commonly called *being smart* (Bourdieu, 2001; Breen & Lindsay, 2002). Also, science is the discipline considered reserved only for the smartest students (Hughes, 2001; Olitsky, 2007), thus grades are particularly essential to the figuring of what it means to be a good science student. This cultural model, in which good science students get good grades, was reified in the figured world of the science program through artifacts including a high grade cut-off for direct acceptance; a system in which failing grades or slow accumulation of credits resulted in probation or expulsion; a rigid, test-based assessment system that included a common final exam; and the use of the R-score (a method of ranking students based on grades and class average used for university admission in Québec). Perhaps the figuring of grades as an index of suitability for participation in science was best exemplified by this excerpt from the letter mailed to new science students and posted online in August 2009, “We are also proud of you. Your secondary school marks indicate that you have the potential to succeed at college.” As we will show in the following section, figurings such as these were often damaging to latecomers’ construction of inbound trajectories.

Three Case Trajectories

In this section, we summarize the science identity trajectories of three latecomers, Allie, Shelley, and Naveen, selected as illustrative of inbound, peripheral, and outbound trajectories. Focusing on how the dominant cultural models afforded or constrained their ability to author themselves as moving towards science, as well as how they were able to improvise around the constraints of these models, we provide evidence from their educational trails and narrative data from their journals [J], forums [F], and interviews [I]. A complete mapping of the three educational trails is available as Supplementary Material. The narrative data shown here is only a small sample, selected to be representative of the larger data sets.

Allie’s inbound trajectory. An inbound trajectory is characterized by a positive slope representing increasingly successful identification with science, or acceleration towards science, and thus it gains momentum (as shown in the hypothetical inbound trajectory [A] in Figure 1). Allie was on an inbound trajectory from the very beginning of her first year at Island College, and her inbound trajectory was largely afforded by the science program’s figuring of grades and the paradigmatic trail, because for the most part she fit the image of a successful science student portrayed by these two dominant cultural models. When she diverged from these models, she was able improvise ways to still successfully author her science self in ways that allowed her to persist.

Entry into the program. Allie's parents emigrated from the Middle East four years before she was born. Because Allie planned to study commerce at CEGEP, she didn't take Physics 11 in high school. However, because she had good grades and was in the advanced math/science stream, she took advanced math and Chemistry 11, "I had an extra class I didn't know what to take, so I took chemistry" [I]. Allie's sequence of courses in high school deviated only slightly from the paradigmatic trail for direct entry into pre-university science; she was missing a physics course and received a low grade in chemistry. When Allie changed her plans and decided not to pursue commerce, but instead to apply to study science at Island College, she was well positioned to gain acceptance into the science preparatory program. The relative ease with which Allie was able to make this switch illustrates the momentum provided by her near alignment with the paradigmatic trail in high school. In her narratives immediately upon entering the preparatory program, she authored herself moving more quickly towards science than before she began the program, even in her first forum posting (Table 2, B1). Such early narratives, in concert with her educational trail, located Allie on an inbound trajectory at the start of her first year of college.

In order to understand how Allie was able to sustain this inbound trajectory, we now explore how her educational trail and continued good grades in CEGEP afforded her ability to successfully author her science self through her stories of recognition, connections between science and her life, and projections of her future. Importantly, we will show that, due to the affordances the program offered Allie, over time she gained more resources with which she could author herself more regularly and more firmly as moving towards science. This increase in her ability to identify with science (acceleration towards science) meant that her inbound trajectory gained momentum, affording her continued persistence in the program.

Stories of recognition. Upon entry into CEGEP, Allie's was able to make sense of how she, someone who never intended to pursue a future in science, could be a legitimate science student. She immediately authored herself as a having a place in science using her history of recognition for good grades in the advanced stream in high school, saying that she "passed pretty well" (A1), evidently drawing upon the pervasive good grades and paradigmatic trail cultural models. Her educational trail in CEGEP shows that she continued to receive recognition in the form of good grades during her first year. In her first semester at college, Allie took a full course load. She did well in these courses and was accepted into the pre-university science program at the end of her first semester, receiving institutional recognition of her legitimacy. In her second semester, she again took a full course load.

There was one aspect of the grades model with which Allie regularly improvised to exert an upwards force on her trajectory, thus enhancing its inbound momentum: hard work equals better grades. This also was a part of the figured world of the science program, as evidenced by the following excerpt from the welcome letter referred to earlier: "If you work hard and consistently, seek help from your teachers when you need it, and keep your goals in mind, you should do fine." Allie used this creatively by often narrating herself as a lazy student, thus making sense of instances of lack of recognition without authoring herself as not being smart enough to do science. In this way, she made sense of her borderline passing grade of 60% in Calculus 2, "Cal is one of those classes where you have to sit at home and do a lot of practice, and again, I'm-I'm pretty lazy, so I don't do a lot of practice and stuff" [I]. Even when her grades were good, she used this figuring to author herself as capable of getting even better grades, if she worked harder. Referring to a physics course she said, "Again, not a lot of effort . . . But I finished pretty well. I got an 83 on my final so that was good" [I].

Allie began to receive other forms of recognition that helped her to author herself as moving with greater velocity towards science. In the beginning, she repeatedly relied on the story of her brother, an outsider to science, telling her she should study science to make sense of why she was in science (e.g., A2). Then, mid-year, she wrote about a friend recognizing her as someone who was enough of a science person to be interested in physics outside of school, and thus as someone who was moving towards science (A3). However, she placed her friend in a position of power, where Allie was learning from her friend who was in the pre-university program rather than the preparatory program. It wasn't until later that she authored herself as active in giving recognition to her peers (A4-6). Through these stories of increasingly powerful recognition by self and others, we can see Allie's inbound trajectory increasing in velocity towards science and thus gaining momentum, going from "considering taking science" to being a part of science, "*we* liked it."

Importantly, as demonstrated in these stories of recognition, Allie authored herself as part of the elite world of science throughout her first year, getting better at it as she acquired resources to assist in this authoring. Through statements like these, "I was the type of person capable of doing well, " "nerdy," and "making fun of social students," Allie made claims about who can do science, where recognition is reserved for those select few who are smart enough to succeed, a model that reproduces marginalizing forms of recognition.

Connecting science to my life. At the start of her first year, Allie was only able to narrowly connect science to her life, where science was seen as something that helped people, like her family members, to know more (Table 2, B1-2). During her first year at Island College, however, Allie was able to increasingly author science as connected to her life, again supporting her location on an inbound trajectory. As time went on, she authored herself as one who knew more because of science, moving away from science as answers and towards science as a framework for understanding her world, even authoring herself as a curious person, a trait associated with scientists (B3-4). This allowed her to reconceptualize herself within science, in opposition to her past self, who was outside of science and therefore didn't see the world in the same way (B5-6). Importantly, it was only because she was already accelerating towards science, that is, she was receiving increasing recognition as someone who belonged in science, that Allie could draw on this model in which science students see the world differently than non-science students.

Projecting my future. Throughout the study year, Allie also began to more confidently project a future in science (Table 2, Column C). Her initial projection was vague and shortsighted ("give it a try" C1/2), and she tended not to speak about her future in science at all. However, she quickly moved to success in science being a goal (C3) and was able to narrate herself as an active participant in science rather than just trying it out (C4). By the end of the year she had chosen a career in engineering (C5-6). At this time Allie was also able to envision her trail aligning closely with the paradigmatic trail, "I'm still trying to finish in two years . . . If I can get linear algebra this summer, I'll be taking biology for sure next semester, and maybe . . . I have to ask if I'm allowed to do 4 science classes" [I]. This projected sequence would require Allie to improvise with her scheduling, even considering the option of overloading. Permission to take four science classes (overload) was usually granted only if the student had a history of good grades, and thus adherence to the grades model would continue to exert an upwards (affording) force on Allie's inbound trajectory. Similarly, Allie's above average grades provided a resource to project a good R-score and thus acceptance into engineering at university, “I’m still above average. My [R-score] should be good” [I].

Summary. Although she entered as a latecomer via the science preparatory program, Allie used the prescribed course sequence and timetable and the institutional emphasis on grades, comparative averages, and R-scores to increasingly author herself as a legitimate science student and create a storyline of herself as moving through the program as expected. These requirements for progress, laid out as cultural models in multiple college documents, became resources for students like Allie in creating “feeling as well as meaning” (Varelas et al., 2005, p. 2) in their relationship with science. In Allie’s case, her close approximation of the paradigmatic trail in high school, new sources of recognition, and early institutional recognition for good grades created an increasing velocity towards science, adding to her trajectory’s momentum. However, other cases will illustrate that the balance between constraining cultural models and successful improvisation frequently tipped in the opposite direction, preventing or dismantling inbound trajectories.

Shelley’s peripheral trajectory. A peripheral trajectory is characterized by mixed success identifying with science, where the ups and downs essentially cancel each other out over time, resulting in an unchanging trajectory near the margins of science (as shown in the hypothetical peripheral trajectory [C] in Figure 1). As we will show, Shelley’s ability to author herself as moving towards science fluctuated in this way throughout her first year at Island College, and she experienced no acceleration (change in identification) towards or away from science. In contrast to Allie, Shelley’s trajectory was strongly constrained by the science program’s figuring of grades and the paradigmatic trail, and she had to constantly improvise just to maintain her peripheral trajectory. We will show how Shelley sometimes successfully improvised ways to resist the marginalized subject positions and their associated lack of motion towards science imposed by the cultural models. Thus, while unable to construct an inbound trajectory, she was able to avoid being shifted onto an outbound trajectory, persisting despite a myriad of obstacles during her first year at Island College.

Entry into the program. Shelley is a second generation Canadian, her grandparents having emigrated from England. We describe Shelley's educational trail as a rollercoaster that began as far back as the start of high school. Because Shelley was in the regular stream in Grade 10 and 11, she didn't take any advanced science or math, but before graduation Shelley became interested in the Environmental Wildlife program offered at City College, another local CEGEP. After passing her Grade 10 make-up courses at City College, she decided to try to access the pre-university science program instead, and thus took the make-up courses for Grade 11 chemistry, physics and advanced math. She did well in chemistry but failed the rest and was denied access to the City College science program. Instead of giving up, Shelley applied to the Island College preparatory science program to try again. Shelley's educational trail suggests that she was on a peripheral trajectory at the start of her first year at Island College, attempting to access postsecondary science for the second time. In her first journal and forums, she authored herself as stuck in the same situation, having to fight to access science, "Here I am trying again because I am really determined!!" (Table 3, C1). In the following sections we will show that the downwards pull of the constraints of the science program on her motion towards science meant that she had to keep fighting just to remain on her peripheral trajectory, barely moving towards science.

Stories of recognition. Shelley's rollercoaster performance in high school was reflected in her stories of recognition throughout her first year at Island College (Table 3, Column A) indicating that she was not free to take up any subject position (Holland et al., 1998). Instead she had to improvise on her history-in-person, a history that consisted of many experiences of not being recognized as moving towards science. In her narratives, she tended to focus on instances of high and low grades (A1-4), as well as differences between her educational trail and the paradigmatic trail in high school (A2-4,6).

A key way that Shelley tried to make sense of the lack of recognition she received when she earned low grades, was by countering with stories of high grades and success (A1-4). However, Shelley's attempts to use the grades cultural model to author herself as moving towards science were hampered by the paradigmatic trail model. For example, her use of "low/er" (A3-4) portrayed her good grades as less valid because they were not in the advanced or science stream. Even though Shelley had as many successes as failures in science, the grades and paradigmatic trail models hampered her capacity to identify with science in the present.

At Island College, Shelley's educational trail continued its rollercoaster pattern and thus her institutional recognition in the form of grades was up and down. In her first semester at Island College she passed both her math and physics make-up courses with grades above the class averages and was accepted into the pre-university science program. The next semester Shelley took the first required chemistry, calculus and physics classes. She dropped chemistry, failed calculus and barely passed physics. Despite these difficulties, she registered for another semester in science.

Because the grades and paradigmatic trail models tended to force Shelley away from science, in her stories of recognition she improvised with other resources to make sense of her past. These improvisations included a revision of the cultural model of grades as the undisputed reflection and measure of her success and value, to one in which her grades depended on the intertwined resources of having a good teacher (A1,3), feeling free to ask questions in class (A4), and how hard she worked, “Science is difficult! I have to work really hard” [F]. Even at the end of her first year in college, Shelley still drew on these resources, using them during an interview to make sense of a second semester failure (A5). By figuring her failures as due, at least in part, to her teachers and her own lack of effort, she was able to successfully resist the downwards pull of being recognized as not being smart enough to succeed in science imposed by the cultural models of grades and the paradigmatic trail.

Connecting science to my life. Throughout her first year, Shelley drew on a very limited set of resources to connect science to her life as she attempted to author herself as moving towards science (Table 3, Column B), leaving her stuck at the end of the year narrating why she liked science in the same way as at the beginning of the year. She continued to express her affinity for science only in opposition to other fields that she disliked. Her inability to access new resources to author a strong connection between herself and science contributed to her peripheral trajectory. Although on the surface, Shelley’s narratives of how science is connected to her life seem unaffected by the models of grades and the paradigmatic trail, her minimal success at this form of authoring her science identity suggests otherwise. Rather, the marginalizing forces she regularly experienced due to the dominance of these models in the figured world of the science program may have hindered her from learning new ways of connecting science more closely with her life. In contrast, Allie’s location on an inbound trajectory afforded her ability to author her science identity by drawing on a model in which science helped her see the world around her differently than the previous year. However, Shelley’s peripheral trajectory did not allow her to draw on that resource. How could she say she saw everything differently when she was in the same situation she was a year ago—fighting to maintain her motion along the margins of science?

When connecting science with her life, Shelley usually drew on a model in which science was about finding the right answer as opposed to writing and forming opinions, which she termed, "bullshit" (B3). Describing herself as finding writing difficult, this model of science helped her author herself as moving towards science (B1-6), but only barely. Usually, Shelley used this model in its negative form, authoring herself as not liking the other options, rather than as feeling a strong affinity for science. In this way, she tended to author herself as skating along the periphery of science, suggesting that she might choose another program over science, if she found one that didn't involve much writing.

The only time Shelley hinted at finding science genuinely interesting was in her first forum in which she expressed an interest in health, which she linked to science, "I am now really interested in fitness and nutrition, thats why I am studying for sciences." However, despite continuing to express an interest in human health in her daily life (e.g., she wrote about getting health advice from magazines in a mid-semester journal) and taking a Humanities course in nutrition, she never again directly connected it to the science program, health was not a topic covered in any science course except tangentially in the elective on human anatomy, a course that was difficult to fit into latecomers' schedules due to the recommended sequence of courses. In contrast, the science departments offered many health-related courses for non-science students (e.g., Diet, Weight & Diseases, Nutrition Today, and the Biology of Sex). While it was common to try to get non-science students excited about science through courses intended to connect with their interests and lives, the same was not done for the science students, who were likely assumed to already be interested enough in science.

Projecting my future. Shelley also experienced mixed success at projecting a future in science (Table 3, Column C), contributing to her location on a peripheral trajectory. To project her future, Shelley repeatedly drew upon the idea that science *opens doors* (C1-2,6). Science opening doors is part of the larger cultural model of the paradigmatic trail, where success in high school science leads to CEGEP science, which leads to university science programs and prestigious science careers (including medicine), if you follow the right course sequence. This resource, however, conflicted with Shelley's expressed lifetime interest in being a teacher (C3). When pressed to write more about this, Shelley drew on the paradigmatic trail model, explaining that being in the science program made her want to push for a *bigger* career (C4). She repeated this sentiment again at the end of the year, "Well if I go through the science program I kind of wanna do something that would be like, like a doctor or something" [I]. Unfortunately, Shelley's R-score was already too low to gain access to medical school, and she knew it (C5). In this way, the paradigmatic trail model, and its implicit narrow construction of desirable science fields, interfered with her genuine interest in science teaching and left her unable to think of another possible future. Thus, yet again, the models of grades and the paradigmatic trail constrained her ability to identify with science, keeping her on the periphery of science.

The paradigmatic trail model also constrained Shelley's ability to project a future in science by increasing the time pressure for graduation. Like Allie, Shelley considered overloading and taking a summer course to better align with the paradigmatic trail, "I'm trying to plan it out so I don't have to stay here that much longer cause I've already been in college for two years, but it's going to be a lot next semester if I take four science courses" [I]. Shelley had not yet passed three science courses in a semester. Overloading to hasten graduation would likely result in failure and academic probation. Consequently, the paradigmatic trail not only made it difficult for her to identify with science, her attempts to adhere to it threatened to force her onto an outbound trajectory.

Summary. Shelley's ability to identify with science was largely constrained by the grades model and the paradigmatic trail model. These constraints were strong enough that, despite desperately trying to find ways to identify with science, she sometimes wearied and authored herself as moving away from science (A6), an unfortunately easy task given the power of the dominant models. It is instances such as these that reveal the difficulty of maintaining peripheral trajectories, let alone accelerating from peripheral to inbound, for students like Shelley, that is, students whose educational trails drastically differ from the traditional science student. The tendency of the dominant cultural models of the figured world of the science program to force Shelley away from science meant that Shelley had to constantly exert effort to find ways to identify with science simply to maintain a peripheral trajectory. And, since her fluctuations between identification and disidentification with science meant her trajectory didn't gain momentum (for example by learning new resources to connect science more closely with her life), she had little to rely on to help carry her through rough patches. During the middle of her second semester, Shelley spoke to an academic advisor. She decided to remain in science another semester, "I think I'm going to see how next semester goes?" [I], suggesting she was on the cusp of shifting to an outbound trajectory.

Naveen's inbound→outbound trajectory. A shifting trajectory is characterized by a change in its trend, that is, a change in the direction of the trajectory's slope or acceleration. For example, Trajectory B in Figure 1 illustrates a hypothetical trajectory that shifts from inbound to outbound, signaling a change from increasing identification with science, to decreasing identification with science. Naveen's case mirrors this; despite entering college on an inbound trajectory, which he maintained into his second semester, Naveen shifted to an outbound trajectory at the end of second semester and left the science program. In what follows, we show that the cultural models of grades and the paradigmatic trail, embodied in the form of the probation system, overpowered his previously successful use of resources to identify with school science, forcing him onto an outbound trajectory and eventually accelerating him away from science and out of the program.

Entry into the program. Naveen attended high school in the Middle East, where, according to his narratives, he was very engaged in science (e.g., Table 4, A2). However, political turmoil in his native country brought him to Canada in his early twenties where he "turned into the job market and got stuck there for more than a decade" [J]. During this time, Naveen still found ways to participate informally in science. For example, he read a wide variety of science books and conducted experiments in his garden, "I have been puzzled by the different ratios of NPK (Nitrogen, Phosphorus, Potassium) that each plant specifically requires . . . These experiments have enormously contributed to my main interest in science . . . I hardly know anything else that could be as fulfilling" [F]. Through these improvisations over many years, Naveen authored himself as moving towards science, albeit very slowly, so that, when the opportunity arose for him to access formal science education at the age of 39, he took it. The momentum supplied by his past success in school science combined with his continued use of science in his everyday life facilitated his inbound science trajectory at the start of his first year at Island College. This is evident in his first narratives, in which he authored himself as being able to move more quickly towards science now because, not only had his circumstances changed, he had never really stopped being involved in science (e.g., Table 4, A1, C1).

Stories of recognition. As we will see, the institutional recognition that Naveen received during his first year in CEGEP waned in his second semester. However, like Allie, he used a variety of other resources to author stories of recognition which demonstrated increasing velocity towards science. For example, he often drew on resources from outside the science program to author himself as someone who belonged in science. Nonetheless, by the end of second semester, his narratives became dominated by institutional non-recognition, signaling his abrupt shift to an outbound trajectory (Table 4, Column A).

In Naveen's stories of recognition in the early part of the year, the recognition came from himself rather than others (A1-A3), and the resources he used to author his science identity didn't come from the dominant cultural models of grades and the paradigmatic trail, but rather from his life outside of school. For example, he told stories in which, over the last ten years he engaged in science on his own by reading books and experimenting in his garden at home. In these stories, Naveen used a lot of scientific terminology (e.g., "beneficial predatory insects," "play with the results to optimize them," "theories behind the quantum mechanics"), a language that most first year students did not use and which served to author him as moving towards science.

Naveen also drew on resources from other areas of his life to author increasing identification with science. Most notably, he drew on his special circumstances as a political refugee and a father to make sense of his lack of formal recognition as a science student in the intervening years (A1). Thus, although his life circumstances had kept him out of school science, once in the program they served as a resource for improvising ways to make sense of his differences from the paradigmatic trail, and thus helped him to identify with science.

During his first semester, Naveen was successful in his two science courses, obtaining immediate institutional recognition in the form of grades that were above the class averages, contributing to his inbound trajectory. However, he never focused on these grades in his stories of recognition, instead drawing on his self-perceived comprehension of the material as a resource for measuring his success in science. This improvisation, likely derived from his informal science activities, had the potential to be a powerful resource for supporting his inbound trajectory. For example, by focusing on his comprehension rather than his grade, he was able to narrate an overall positive experience in Calculus I despite it being his lowest grade of the semester, at 75% (A4). It even helped him make sense of his failing grade in second semester Calculus II in a way that could have helped him continue to move towards science, “I would like to do it again so I understand it really well because probably I will need it in the future” [I]. However, at this point, as we will show next, Naveen was already outbound and such authorings were only able to slow, not stop, his outbound trajectory, perhaps preserving the possibility of a return to school science in the future.

In understanding what happened to Naveen, we look to his educational trail and changes in his self-authoring during the year. In his second semester, Naveen took three science courses and Physical Education. His participation in one more science course than in the previous semester suggests he was still on an inbound trajectory. However, partway through the semester Naveen’s parents both experienced serious health problems and moved into his home. This added burden greatly limited his study time and he dropped Physical Education. Unbeknownst to Naveen at the time, students are required to pass a minimum of three courses per semester or they will be placed on probation. Once on probation, they must meet the same standards the next semester or they are expelled. After dropping a course, Naveen was only registered in three courses. His grades in chemistry and physics were above average but he failed calculus and was placed on probation. It was at this point that Naveen shifted to an outbound trajectory. Worried about expulsion the next semester, he soon switched out of science into the computer science career program.

Signaling this shift to an outbound trajectory, at the end of the year, Naveen's stories of recognition changed, focusing almost entirely on his institutional non-legitimacy. He expressed feelings of pain (A5) and of being accused of wrongdoing (A6). Through such stories, we gain insight into the symbolic violence (Bourdieu, 1977) inflicted by the paradigmatic trail and good grades models.

Connecting science to my life. Naveen's authoring of connections between science and his life demonstrated a similar pattern to his stories of recognition; he built on his strong interest in science in his everyday life, acquired new resources that he used for a time, but then experienced a dramatic shift late in the year (Table 4, Column B).

At the beginning of the year, Naveen expressed an altruistic worldview in which serving humanity was extremely important and science was the best way to do that, therefore he belonged in science (B1-2). As time progressed, he learned new ways to connect science to his life, adding to the momentum of his inbound trajectory. For example, he was able to use his children to narrate himself as highly motivated, thus more closely linking his day-to-day life with his studies (B4). He also developed an intense interest in math and physics (B3), as well as laboratory work, "[Labs] make us think more deeply about how those elements work and interact. I think that true learning occurs when one gets hands on experience. I usually never forget about something that I was able to prove by the way of experiment" [F]. In all such narratives, Naveen used passionate language to author himself even more strongly as being where he belonged, moving with high velocity towards science (e.g., “great honour,” “fulfilling,” “the most rewarding path”). In contrast, at the end of the year, after being placed on probation, Naveen figured science in a pragmatic rather than an idealistic manner, where it required more effort than he could give (e.g., B2 vs. B5). Importantly, he did not stop expressing a passion for science, but rather, like his stories of institutional non-recognition, he authored the science program as making him choose between his family responsibilities and science (B5-6), thus forcing him onto an outbound trajectory.

Projecting my future. At the beginning of the year, Naveen authored a future career in science, made possible by his family responsibilities (Table 4, C1-2). As time went on, although he remained unable to project a specific career goal, he was able to definitively project a science-related future (C3-4), signaling an inbound trajectory, until his trajectory shifted to outbound in the second semester (C5-6).

Throughout the year, Naveen did not project himself as working toward any specific career in science, rather he explained that his special circumstances as a single father, and later a caregiver for his parents, meant he had to proceed slowly (C3-4). In this way, while constraining his ability to project too far ahead in science, his family responsibilities offered a powerful resource for resisting the downwards pull of the paradigmatic trail cultural model by allowing him to envision proceeding at a realistic pace that offered more chance of success. However, through probation, the model of the paradigmatic trail was eventually forced on him, bringing to the forefront the risk he was taking by being in science, a program that left little margin for error, regardless of one’s personal circumstances (C5). Accordingly, he switched into a more accommodating program, “If [computer science] is, in terms of the loads, umm, accommodating to me for my, with my problems and situation, then maybe I should be doing this. So I don't go into something that is going to push me to limits" [I].

Despite wanting to be in science, the constraints of the program combined with Naveen's family duties meant that, at that time in his life, he experienced a marked decline in identification with science compared to previous months, and thus he shifted to an outbound trajectory. Naveen's case points to this important distinction: there may be a significant difference between a person's aspirations toward science and their ability to increasingly identify with science when confronted by prevailing cultural models, that is, to construct an inbound trajectory. Naveen's relatively abrupt shift from inbound to outbound has been essential to us in understanding how a latecomer's trajectory can be drastically constrained by the figured world of the Island College program despite a consistently stated desire to continue.

Naveen's expressed intent to one day return to science despite his current outbound trajectory also highlights the importance of time scales in trajectory research. It is possible that Naveen may later return to postsecondary science and eventually succeed in attaining a science career (although it is now three years later and this has not occurred). If so, a longer term study might scarcely notice the downward trend (outbound trajectory) at the end of his first year, as it might not greatly affect the overall trend of his longer trajectory. However, regardless of what happens later in Naveen's and the other participants' lives, our focus on their first year in the college science has allowed us to explore the complexity of latecomers' identification with science during this critical transition period.

Summary. Naveen's authoring of self in science highlights the complexity of his trajectory through the science program, which was inextricably intertwined with his trajectory through other worlds, most importantly, his family life. His family responsibilities sometimes afforded his identification with school science and, at other times, acted as a constraint, but in all cases, the importance of his family to his motion relative to science was a common thread running through his narratives. Although everyone's identification with a particular context such as science intersects with and is influenced by multiple overlapping worlds (Catherine R. Cooper, 2011), it is only in certain cases that participating in science can threaten one's participation in that other world, and vice versa. Many studies have already shown how students' identification with certain genders, races, and socio-economic statuses can hinder their ability to identify with science, unless they are willing and able to weaken their participation in these other worlds, or in rare cases, are able to improvise ways to negotiate positions in both worlds (e.g., Carlone & Johnson, 2007). Although Naveen was initially successful in such improvisations, ultimately he was no longer able to envision a way to persist in school science without risking his ability to be a good father and son, and so he shifted onto an outbound science identity trajectory and quickly left the science program. By leaving no room for his other worlds, the program's emphasis on grades and the paradigmatic trail as determiners of legitimacy rendered impotent all of the resources that Naveen had gained both outside and inside of his formal science education.

Discussion

Theorizing and Operationalizing Identity

Before we summarize our findings and discuss their implications for science programs, we will highlight our study's contributions to the complex task of studying the "ongoing, cumulative, and contentious nature of identity work" (Barton et al., 2013, p. 37). In this paper, we strove to better understand the persistence of latecomers to science through an exploration of their science identity trajectories over one year as they moved into post-secondary education. Few empirical studies provide documentation of identity constructions over extended periods of time, such as this, and during such critical transitional time periods. Responding to the considerable "conceptual and methodological challenges" (p. 45) inherent in such studies, Barton et al. (2013) relied on two sets of data: the roles, resources and strategies of action that students employed during participation in science; and the material and semiotic identity artifacts that were evident.

In contrast, we chose not to study in-the-moment identity work through participation in science (e.g., we do not report on the latecomers' actions in their science classes). Instead we focused on the self-authoring and making sense of experiences that is ongoing in people's lives and was shared with us in interviews and reflective writing. In this way, we gained insights into another aspect of identity work that continues after an experience takes place, but still represents students' attempts to author themselves in relation to science. As Urrieta (2007) explained, we reconceptualize ourselves through participation as well as through making sense of that participation. By investigating the cultural models drawn upon in latecomers' narrative figurings of self, we extend the power of cultural models, in that we see them as shaping, not only science participation and in-the-moment identity work, but also the self-authoring that students do as they make sense of their experiences of recognition and non-recognition, which may be temporally distinct from the experiences themselves. Whereas others have applied Holland's notion of thickening of identities to students in science, looking at how identity sediments and traces become salient in future in-the-moment identity work, our research recognizes that this thickening is ongoing, as participants do identity work in their thinking, writing, and talking about themselves in science, adding new meanings to their identities. Thus, we illustrate another approach to the study of science identity trajectories that draws upon other types of data and conceptual underpinnings.

This approach also allowed us to break apart Nasir, Hand and Taylor's (2008) category of ideational resources that are used in identity work. They conceptualized ideational resources as ideas about oneself and ideas about what is valued and good in a given context. While recognizing the interconnectedness of these sets of ideas, we examined them separately, using students' sense making of their experiences (ideas about self) to gain insights into the cultural models (ideas about what is valued and good) that shaped these ideas of self. By doing this, our analysis of interviews and reflective writing enabled us to see, not only the resources students used to conceptualize themselves (Nasir et al., 2008), but also how the figured world of the science program, embedded in the wider figured worlds of science and education, shaped students' resources and, therefore, their trajectories. Shanahan and Nieswandt (2011) highlighted the need for studies to specifically explore the structure of school science, viewing it as an entity embedded within and overlapped by the larger figured worlds of science and school, but also as distinct, with its own cultural models that ultimately define what it is to be a successful science student. By paying attention to the institutional level figured world in our analysis, we were able to make claims about what Barton et al. (2013) called "historical and cultural norms" (p. 43) and Nasir, Hand and Taylor's (2008) called "historically rooted collective narratives" (p. 204). In this way, attention to the salient cultural models drawn upon by latecomers helps us to see how aspects of institutional structure often provoke or nurture "critical shifts in trajectories" (Barton et al., 2013, p. 37), and this allows us to suggest changes in structure that might reduce shifts to outbound trajectories.

Lastly, this study offers a new way of operationalizing, conceptualizing, and representing science identity trajectories. We view identification as a *motion* towards or away from science, which we analogize to *velocity*. This analogy allows us to draw upon a number of related mathematical and physics concepts. For example, the *curve of best fit* provides an easy visualization of the shifting trends in identification that comprise identity trajectories, such as the inbound, outbound, and peripheral trajectories presented in this paper. The concepts of *slope* and *acceleration* provide a useful way of talking about long term processes of identification, which can speed up or slow down and even change direction. The direct relationship between *force* and change in velocity allows us to envision figured worlds and their cultural models as exerting constraining or affording forces (depending on how they were used), thus accelerating trajectories towards or away from science. And, because velocity (identification) is directly proportional to *momentum*, our analogy also helps us to understand and visualize the temporal thickening of identity and how, as Barton et al. (2013) explained, "at any moment of identity work, [peoples'] identities bear momentum toward their future sense of self(s) in science that drive them to interact with individuals in a particular way when engaging in activities" (p. 66). We believe that, by using physical concepts such as velocity and force to represent abstract concepts such as identity and cultural models, this analogy has potential for advancing research in this area. Analogies can play a role in problem solving, perception, explanation and communication. By transferring meaning from one subject to another, a new analogy may bring our attention to new aspects of things or it may provide language for talking about things that have been difficult to describe or visualize. In our work, we have found that this analogy has become a valuable resource for making sense of persistence and trajectories in science at various grain sizes. We suggest that it might provide a new resource for improvisation by others working in the figured world of research around identification with science.

Implications for Supporting Persistence of Latecomers to Science

Our research provides evidence that science identity trajectories of latecomers were shaped, and in many cases constrained, by the cultural models in the figured world of the science program. These cultural models make available a narrow range of resources for latecomers, thus truncating effective improvisation and contributing to the instability of individual trajectories. We also provide evidence for the idea that the thickening of identity is related to the accumulation of resources, and this thickening or momentum can propel students towards or away from science. Once established, this momentum is difficult but not impossible to counteract. Of the nine latecomers who participated throughout the year, only two were able to sustain inbound trajectories (like Trajectory A shown in Figure 1), highlighting the instability of latecomers' trajectories. We theorize that, unlike a traditional student whose inbound trajectory has been gaining momentum (that is, a thickening of sediments of identity) since the start of high school or earlier, a latecomer's inbound trajectory is newly formed and with relatively low momentum and thus is more easily shifted away from science if the student experiences challenges to identifying with science. An awareness of the power of thickening and momentum of identity trajectories makes it essential to support latecomers' identification with science from the very beginning of their postsecondary science education and in particular at transitions to each new stage (Johnson et al., 2011).

The detailed analysis of cases provided in this paper moves us beyond the student integration and student attrition models frequently used in the persistence literature (Finnie & Qiu, 2008; Xie & Killewald, 2012) in that the cases show the importance of improvisation to latecomers' ability to persist in science. Even Allie, who was on an inbound trajectory throughout the study, had to improvise to remain inbound. For all latecomers, improvisation involved authoring themselves within and through the cultural models of the program by using resources in new ways and acquiring new resources. There is, therefore, a need to recognize the negative positioning commonly imposed by the narrow cultural models of grades and the paradigmatic trail and to make available a wider variety of resources (and thereby a less restrictive view of what is valued in the science program) that can support latecomers' identification with science. Drawing from the three cases, we suggest a number of changes in cultural models and resources that might support the thickening of latecomers' science identities in the inbound direction.

First, Shelley's and Allie's efforts to graduate quickly and Naveen's attempts to make sense of and work around his slower than normal progress demonstrate the need for many acceptable trails through the program and for resources that help latecomers make sense of their progress in ways that afford their ability to identify with school science. For example, rather than making only the paradigmatic course sequence publicly available, an interactive form could be provided, which includes summer and intersession courses and creates a variety of possible sequences tailored to each student's circumstances. Also, a relaxing of academic probation rules for latecomers would allow them to proceed at a manageable pace without the threat of institutional non-recognition that, as Naveen's case showed, can destroy their inbound trajectories. These kinds of changes would accommodate the growing number of students making their way through science via alternative pathways (Finnie & Qiu, 2008; Xie & Killewald, 2012). Similarly, teachers can support alternative pathways by being careful of the assumptions they make about students' histories and educational trails. Even seemingly harmless comments, like "you guys already learned this in chemistry so I'm going to skip over it," can be demoralizing for latecomers, who often take courses out of the traditional sequence.

Second, the narrow views of science career options promoted in the program seemed to shut down two careers in which Shelley might have been interested—health and science teaching—leaving her unable to project a convincing future in science. Likewise, Naveen's inability to project a specific career goal may have hindered his continued identification with school science. In contrast, Allie's ability to project an engineering career contributed to her inbound trajectory's momentum. Accordingly, latecomers would benefit from resources designed to excite and familiarize them with an array of science fields. Such resources might include a larger range of electives or guest speakers from a variety of science-related careers, perhaps targeted at latecomers.

Third, Shelley's damaging reliance on the cultural model of grades to figure her success in science contrasted with Naveen's initially effective use of his own comprehension to figure his success shows that latecomers need resources other than grades on traditional assessments for gaining recognition. Carolyn R. Cooper, Baum, and Neu (2004) found that forms of authentic assessments were powerful alternative resources for figuring success in science. While such alternative assessments and evaluation processes are not uncommon at other educational levels, they are rare in college science.

Fourth, Shelley's need to be able to ask questions to succeed in science illustrates several points about latecomers' learning. Shelley was in a bind—her history of mixed achievement in science meant that she needed extra resources to learn, but asking questions risked recognition as not being smart enough to do science. Accordingly, Shelley and other latecomers with similar histories of non-recognition would benefit from environments in which asking for clarification or help is accepted and even encouraged. This would necessitate working with instructors to change their instructional approaches and even their personal views of latecomers. This case also illustrates the value of latecomers understanding their own learning needs and suggests that, if resources for this were made available, they might improve student performance and also provide new ways of making sense of the ups and downs of grades.

Fifth, regardless of the trend of the trajectory, we found that both Allie and Shelley worked to make sense of their history-in-person (Holland et al., 1998), particularly related to their high school experiences. This shows the power that prior thickening of identity had on their attempts to figure themselves within the college science program. We saw that it took considerable improvisation to counter the sediments of non-recognition that had accumulated. Thus, the location of the science program figured world within the larger realm of the Québec educational system is evident, in that the students arrived already positioned in certain ways by the system of streaming in high school. This leads us to suggest the reconsideration and renaming of these and similar secondary school policies and practices.

Similarly, our analysis showed that the college science program is nested within another social realm, namely the world of science, and that cultural models from this figured world fuse with those of the science program and create constraints for latecomers. For example, several latecomers reproduced models in which science was seen as a difficult subject that requires extra hard work and that only smart people can do. These figurings, instantiated in the grades and paradigmatic trial models, served as resources that, for most latecomers, hindered identification with the science program. Thus, offering new images of science students, science, and scientist can counter these marginalizing models, and this is a task that should be taken up in concrete ways by institutions looking to support latecomers.

Sixth, Allie's case showed how peer interactions provided her with new experiences of recognition that afforded identification with science. This finding is supported by a literature in which peers have been found to be an important resource for overcoming institutional obstacles to identification in the broader sphere of postsecondary education (e.g., Catherine R. Cooper, 2011; Espinosa, 2011). The forums used in this study provided this type of space, where students were encouraged to talk about and make sense of their experiences in the science program. For this reason, the journals and forums, initially included as part of the research, are now a regular part of the first author's college physics teaching. Despite research showing the importance of such spaces of cultural production (Bretag, 2006; Hagiwara, Barton, & Contento, 2007), these opportunities are rare in college science, and thus we encourage their use as a tool for supporting students' construction of inbound science identity trajectories.

And lastly, another resource that appears lacking, but potentially useful, for latecomers' self-authorings in science is participation in authentic science activities and inquiry, especially those that highlight creativity and other qualities that might facilitate identification with science (Shanahan & Nieswandt, 2009). Reveles et al. (2004) also pointed to this as a resource for building academic science identities as far back as elementary school, but there are few opportunities for engagement in science inquiry in college science.

Like Wenger (1998) and many others, we acknowledge the interconnectedness of learning and identity processes and we view learning as both a cognitive and sociocultural process. Stemming from this view, researchers have studied learning and identity construction as "a matter of engagement, participation, and membership in a community of practice (Nasir & Cooks, 2009, p. 42) with attention given to student practices in science-related activities in school as well as in other contexts. As mentioned, a similar focus on science practice in the classroom was not undertaken in this paper, and hence we are limited in the specificity of the claims we can make about implications for teaching and learning. However, along with the suggestions already provided, we draw briefly from the larger research project in which this paper is situated to make some broader suggestions for how classroom practice can better support latecomers' identification with science. More specifically, we draw from classroom observations that were conducted the following year and revealed a certain pattern.

In CEGEP, both preparatory and pre-university science courses generally consist of 3 hours of lecture and 2 hours of lab per week. While some lectures are a bit more interactive, in most the teacher is at the front of the room writing or displaying notes, working problems on the board, and occasionally asking questions usually in a triadic dialogue style (Lemke, 1990). In the labs, after an introduction from the teacher, students are generally on their own, working in pairs. The lab activities tend to involve finding or validating constants or other information that is already known. Perhaps due to their place in the institutional sequence, CEGEP science courses focus less on doing science and more on presenting the material that is believed necessary for students to be well prepared when they start university science. The focus is very much on the content of science, not the practice of science. This reality, in part, informed our methodological choice to utilize out-of-class data sources in this paper. Furthermore, this characterization highlights an additional challenge that latecomers experience in trying to establish a trajectory toward science. In CEGEP there are few opportunities for latecomers to participate in something that resembles a community of science doers or to develop "practice-linked identities" (Nasir & Hand, 2008, p. 147) in science, as there are in secondary school or in science clubs when students are engaged in authentic science inquiry or when their out of school knowledge is leveraged in doing science. Thus, latecomers are denied these opportunities to reconceptualize their selves through doing science. The recent increase in active learning and inquiry approaches in post-secondary science education (DeHaan, 2005) may soon provide opportunities for authentic science engagement and additional resources to allow students, such as the latecomers, to reconceptualize themselves as science thinkers and doers.

Conclusion

Compared to many other systems, Québec's postsecondary science education system is quite flexible. The Island College science preparatory program, which can lead into the pre-university science program, offers an alternative route into science, thus ostensibly increasing inflow into the science pipeline. However, as shown in this paper, under the flexible surface lie hidden structures through which the science program is figured as elite, only for those whose educational trails align with the paradigmatic trail and who get good grades. In this figured world there is little room for latecomers to science whose alternative educational trails and history of mixed academic success mark them as atypical, forcing them to the margins. Such an understanding of the challenges latecomers to science encounter persisting in science adds much needed layers of complexity to the pipeline paradigm. Paralleling Johnson et al.'s (2011) findings for women of color, "far from needing to be persuaded to stay in the science pipeline, [latecomers are] fighting desperately not to be spewed out of it" (p. 363).

As the numbers of students following non-traditional routes through postsecondary education continues to rise (Goldrick-Rab et al., 2007), it is increasingly important that research into how to better support latecomers to science be continued. Our work suggests that such research might explore ways to widen the array of resources available to latecomers to provide them with successful ways of authoring themselves as moving towards science. We recommend that future research incorporate data such as classroom observations along with narrative data to facilitate smaller scale recommendations, such as how instructors can modify their teaching to support latecomers' persistence. Also, looking across multiple worlds that latecomers navigate may provide essential insight into students' learning and persistence, but has yet to be tried for latecomers to science (Catherine R. Cooper, 2011; Edwards & Mackenzie, 2008).

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Figure 1: Representations of four of the many possible science identity trajectories a hypothetical latecomer to science may construct *during her first year in CEGEP science*.
Zero on the identification axis represents the dividing line between identification with, or motion towards science, and disidentification with, or motion away from science. The magnified view illustrates a finer time scale and shows the curve of best fit drawn through the scatterplot of points representing motion relative to science. Although shown for only one trajectory, it highlights that *all* trajectories entail shifts and variation in identification over time.

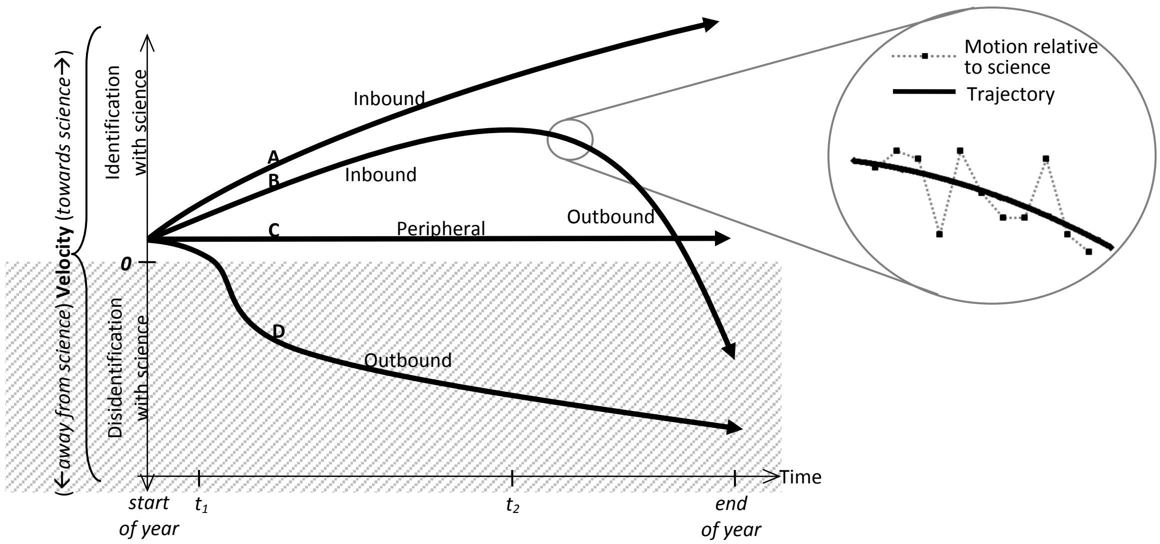


Table 1: Summary of trends in science identity trajectories of nine latecomers to science.

Student	Start of year	1st semester	2nd semester
1: *Allie*	inbound→	inbound→	inbound
2:	inbound→	inbound→	inbound
3:	inbound→	inbound→	peripheral
4:	inbound→	peripheral→	peripheral
5:	inbound→	peripheral→	outbound*
6: *Shelley*	peripheral→	peripheral→	peripheral
7: *Naveen*	inbound→	inbound→	outbound*
8:	inbound→	outbound→	outbound*
9:	outbound→	outbound→	outbound*

*exited science during or at the end of second semester

Table 2: Sample from Allie's narrative data table.

	A: Stories of Recognition	B: Connecting science to my life	C: Projecting the Future
Start of Year 1	My experience in science before grade 11 was okay. I didn't really take it seriously to be honest. I passed pretty well, I just never got into it. [J]	Science was always that really hard subject in school that I wouldn't even think about taking. Now, I see it as a new way of understanding, where questions get answered and you get answers to questions you didn't even know existed. [F]	After some consideration, I decided to give it a try which is why I'm in this physics class. So far so good :) [J]
2	[My brother] tried very hard to get me to consider taking science. Being a commerce student himself, it meant a lot to me that he was telling me that I was the type of person capable of doing well in sciences. [J]	Many members of my family are in the science field and they are the ones that always seem to just know more about the way things work. So that's what science is to me...knowing more. [F]	
Increasing identification 3	The work load can be much at times, but I just have to get used to it. So far, it hasn't been too hard and I feel like I've gotten a lot out of it, knowledge wise and discipline wise.	In high school, I only did about 2 experiments all year, so that definitely had no effect on the way I viewed science. Now that we've done many throughout the semester . . . I see physics and chemistry everywhere around me. [J]	I just set science as a goal and I'm the type of person that tries never to give up. [J]
4	Me and a friend of mine in mechanics have facebook physics discussions. No joke. She supply's me with daily physics nerdy posts. Her last one was about a question on her exam about a moving car and an object. Interesting [J]	A large part has to do with it being a goal and challenge for me, but I have been liking [science] for other reasons. I feel like it's broadened my understanding of everything . . . I guess I'm curious of certain aspects of science. [J]	There is so much more to be learned and discovered and that definitely pulls me to participate more in science. [F]
5	I was sitting with my friends . . . And we were just talking, and we were making fun of social students [chuckle], and it was just like, oh, this is good. I like science. We liked it. [I]	[When you are in science] the way you look at everything is different. And it is different than last year [I]	The jobs offered later on are more something I would like? Like engineering is something I would like probably more than accounting or something? That's good. I like it. [I]
End of Year 6	I was with my humanities class and um, at a farm? And we were a lot of science students I guess. Cause it was like [laughs] something with an incline, and we were like oh let's calculate the coefficient of static friction . . . cause something wasn't falling off. [I]	And I thought about [going into the science program] and I'm like, ok why not? [laughs] Don't lose anything. So I did. And then I like it now, so it's good. [I]	[My parents] would like me to go into like being a pharmacist, or something like that? But no, me I'm more into engineering. I think my brain works better that way. [I]

Table 3: Sample from Shelley's narrative data table.

		A: Stories of Recognition	B: Connecting science to my life	C: Projecting the Future
Start of Year	**1**	I am not going to let a few teachers get in the way, cause I know I can do it. I proved that with my math and science 436 [Grade 10 advanced courses] I got 90% in both!! [J]	I really do not like any of the other programs except science, or see myself in any other program. Science can be difficult at times but I would rather spend my time on a problem then on writing an essay or reading. [J]	I just thought I would have more options in the science program. . . . But I did not do so well in math and physics, so here I am trying again because I am really determined!! [F]
	2	The fact that it was highschool to, there is so much judgement. I guess I wasn't ready for it. So I ended up doing just my 416 math/science and 514 math [regular level], I did very well to. [J]	When I first was looking in to college, I knew I did not want to do anything with writing and definetely not social. The last option was clear, science. I soon discovered that, I like to know there is one answer to the question and not two or more. [F]	I decided I just rather go into science to open all the doors. So I would do chem as planned but as well I would do math and physics, to get into science. [F]
Unchanging identification	**3**	I also did very well in math and science in Highschool even though it was the low courses, with the help of good teachers and studying. [J]	Thats exactly why science is great, yes irratating at times if you can't find the answer. But in the end there is usually one answer, and I like that. No Bullshit lol. No need to formulate an opinion. [F]	I have wanted to be a teacher for most of my life, but not anymore. I do not really have a reason, but if I were to be a teacher I would want teach math or science. But I really do not think I am going to become a teacher. [J]
	4	I never felt very good in science and math because I was in the lower classes. . . I just felt really stupid beside the people in [the advanced] classes and therefore couldn't ask questions. Although when I was in the lower classes I did pretty good, cause I tried and didn't feel scared of asking questions. [F]	I think my experiences in school have helped me to view science in the way that the wesite explains it. In the way that we are taught that most questions have a logical answer and meaning.[F]	I think I just want to push for a bigger carrer . . . I do not think you need to do science to become a teacher . . . And if I complete the sceince program I will have worked really hard and I kind of want to do more using what I have learned. [J]
	5	My [Calculus] teacher, she wouldn't, really explain it. And if I asked her a question, like it was one little mistake I did but she'd make it sound like I'm like stupid. [I]	[Describing why she likes science] And like it you…like on a test. You can, like you can't guess, you have to know it? [I]	*Shelly*: I'm just worried I won't have the marks to get into what I want to do? *Phoebe*: Which would be? *Shelly*: Well like, if I was to become like a s- a type of doctor, then I don't know if I'd have a good enough mark. [I]
End of Year	**6**	When I was in high school I wasn't in the sciences, so I … always think to myself, like why am I here? Like sometimes I think like maybe I'm not supposed to be here. [I]	[Answering why she chose science] Um…because I find social, like all the other courses are English related and writing, and I don't like writing. [I]	But it [science], it opens a lot of options. That's why I'm in it. [I]

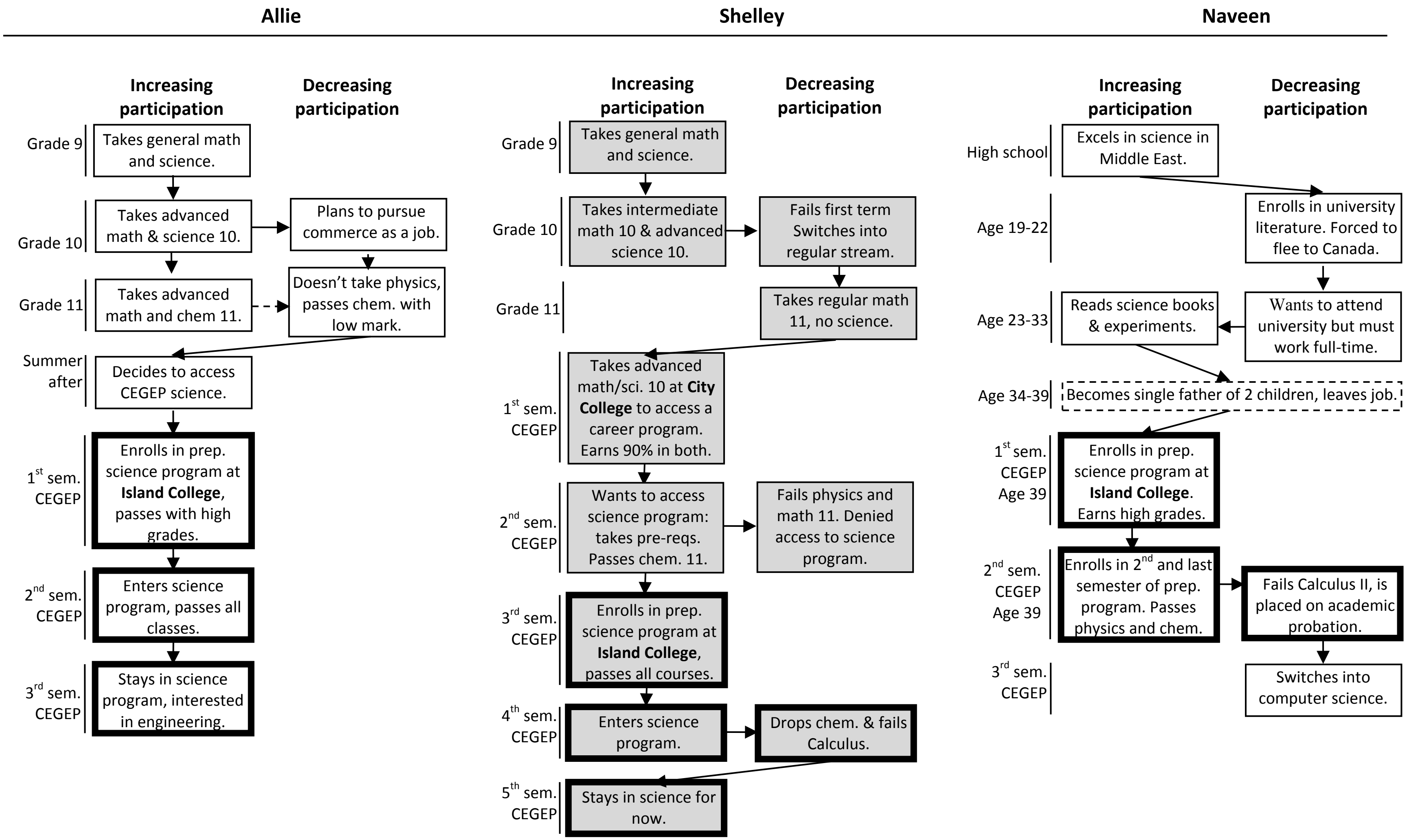
Table 4: Sample from Naveen's narrative data table.

	A: Stories of Recognition	B: Connecting science to my life	C: Projecting the Future
Start of Year 1	Because of certain circumstances and obligations in my life I was unable to pursue my studies . . . I was nevertheless always interested in Physics and Science in general and was constantly reading on those subjects.[J]	Great scientists of ancient and modern times have put progress in science before themselves and have made great sacrifices and even paid the price with their own lives in the name of humanity and in an attempt to make our lives easier and more meaningful. So it is with great honour that I would endeavour to learn about what they have to teach us. [F]	I am now 39 years old and the father and sole care taker of two kids . . . which I don't regret now as it has inadvertently changed my life in a much better direction and has created the prospect of a career that would be more gratifying and more enjoyable. [J]
2	I truly believe that I belong [in science] and that I should spend the rest of my life contributing to it in any way I can. [F]	I personally see Science as the most rewarding path, for those who decide to dedicate their live for the advancement of technology and research for the well being of the humanity as a whole. [F]	The circumstances are right for me to go back to school and pursue what I always wanted, namely a career in Science and I am absolutely thrilled about this journey that I am about to undertake. [J]
Increasing identification 3	One thing I know for certain is that I love Physics and Math. . . . I have never before been so sure about what I love doing. I know as a fact that I appreciate this environment and everything it entails. [J]	I find Physics and Math appealing because it incessantly challenges my mind and pushes me . . . one's level of expertise and experience will compel one to use the shortest and the most effective way and therefore constantly proving to oneself that the more one gains in knowledge the more one will realize how far behind one is, and consequently keeping one always on one's toes. [J]	I do not as a principal, project too long term of a plan in respect to my future career choices, I do however know that it will be Science related. I am in a situation, with my responsibilities and obligations that I have to take it one day at a time and make sure every day is a successful day. [J]
4	After reflecting . . . I realized that maybe [being challenged by my Calculus teacher] was exactly what I needed, in order to rise above myself and go beyond the expectations. [J]	My high motivation mainly derives from the fact that I would like to be involved in a career with Science but also from the fact, that I would like to offer to my kids what I was not able to receive from my parents, namely; help for my Science courses. [J]	I do not generally like to project too far of an objective in the future, however I know, that whatever I will be doing will definitely be Science related. [F]
Decreasing identification 5	[Probation] really hurt me because I-I, I really like, you know, I love [science], it really really hurt me. [I]	But you see, another thing that-that is important for me is . . . I want to avoid any additional stress. And that's why I like, I-I don't know if I told you, because I changed my program too eh? I changed my program to computer science? [I]	I failed one and I was on probation. If-what happens if I do the same thing and something happens again, you know? My mother's situation worsens? This will be like, be completely disastrous. So I have to, I have to keep some space. [I]
End of Year 6	OK, now you're on probation, as if you have been a criminal . . . It affects me, because I know that I have done everything that I could, there is no way that I should be on probation. [I]	I love to be in science, but am I going to do something that will, I dunno, discourage me more? With this situation right now, I don't think that it would be wise to do that. [I]	I know that I haven't abandoned it. It's just, you know like sometimes you have to go a couple of steps back and then go forward again. [I]

Table S1: Five forum topics assigned to all students of the make-up physics course.

Date of Forum	**Topic**
Aug. 24 – Sept. 7	What does science mean to you, and how do you see yourself participating in science (both now and in the future)?
Sept. 14 – 22	What are some experiences that you have had with science OUTSIDE of the science classroom?
Oct. 5 – 26	Reflect on how you have experienced science IN school. Have these experiences helped shaped what science means to you (or not)? Have they made you more or less interested in pursuing a future in science?
Oct. 26 – Nov. 8	Hello, Below I have written two statements about science. Please reflect on these two statements. Do you agree or not? Why? Are there parts you agree with and others you don't? What are they and why? Do you have any of your own experiences that support/refute these statements? 1) Science is 100% objective: (i.e. politically neutral, non-biased towards gender, race, class...) 2) Science is the ultimate authority on all things in our universe. Enjoy, I look forward to your thoughts. Phoebe
Nov. 14 – 22	Hello, welcome to our 5th Forum. Before I get into our topic, I wanted to thank you all for putting so much thought into your forum writings and responses. You've brought up so many interesting ideas and have had some fascinating conversations with each other. I hope it's been as interesting for you as it has been for me. For this week's forum, I would like you to go to the website http://www.project2061.org/publications/sfaa/online/chap1.htm ...and read some or all of these sections: **Scientists Try to Identify and Avoid Bias** **Science Is Not Authoritarian** **Science Is a Complex Social Activity** **Science Is a Blend of Logic and Imagination** After reading them, I would like you to reflect on: a) Whether your experiences IN school have helped you to view science like it is explained in the website, or not. Please elaborate. b) Whether thinking about science like it is explained in the website makes see how you can participate in science more, or less, or neither. ******************************** If you're interested there's also some really interesting reading on the following website: http://undsci.berkeley.edu/ particularly the SCIENCE AS A HUMAN ENDEAVOUR, and SCIENCE AND SOCIETY links. There's also some podcasts at: http://vmsstreamer1.fnal.gov/VMS_Site_03/Lectures/NOSPodcasts/list.htm that you might find interesting. ******************************** Have fun, and as always, I look forward to your conversations. Phoebe

Figure S1: Case students' educational trails.
Bolded boxes denote participation in Island College science and/or preparatory science program.



Preface to Chapter 3

Chapter 2 was aimed at gaining a broad picture of latecomers and some of the challenges they faced persisting in their postsecondary science program. Drawing largely on narrative data, Chapter 2 applied a theoretical framework in which changes over time in latecomers' self-authorings indicated whether they were accelerating towards (inbound) or away from (outbound) science, or clinging to the margins (peripheral) of science. Out of 18 latecomers, only eight persisted through their first year and only two of these were able to construct and maintain inbound science identity trajectories for the entire year. The analysis showed that two dominant cultural models of the Island College science program (the good grades model and the paradigmatic trail model) tended to exert a negative force on latecomers' trajectories, making it difficult for them to persist in science. An essential conclusion of this first paper was that latecomers to science would greatly benefit from an increase in the diversity of resources made available to them for authoring themselves as moving towards science.

Tinto (1997, 2005), a leading authority on postsecondary persistence, has argued that it is within students' courses that resources for persistence need to be made available, because courses are the foci around which schools and programs such as the science program, revolve. Experiences in the classroom and other course-related settings are even more important for latecomers such as Naveen (see Chapter 2), whose age and/or out-of-school obligations means that the majority of their social and academic experiences in the science program takes place in their courses (Tinto, 1997). Building on the findings as well as the theoretical framework created and implemented in the preceding chapter, Chapter 3 examines how latecomers' identity work in their courses forms patterns over time which, shaped in large part by the available resources, contributes to their science identity trajectories and thus affords or hinders their persistence.

Chapter 3 asks the following research question: What overarching cultural models are reproduced in the courses of the figured world of the science program and how do latecomers use the resources made available in their courses to advance their identity work towards science?

Drawing from classroom and lab observations, teacher interviews, journals, and student interviews, Chapter 3 presents an analysis of the resources available for engaging in identity work within the courses of the Island College science program. Following two successfully persisting latecomers, Debbie and Jason, as they participate in their science courses over their second and third semesters, this chapter explores how they drew on these resources to negotiate the process of positioning and recognition as they participated in their courses and interacted with their teachers.

Chapter 3: Identity Work in the College Science Classroom: The Cases of Two Successful Latecomers to Science

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Abstract

Presenting the cases of two latecomers to science who successfully persisted through to graduation in their college science program, this paper explores the figured world of the science program, asking, what overarching cultural models are reproduced in the courses of the figured world of the science program and how do latecomers use the resources made available in their courses to advance their identity work towards science? Drawing mainly from lecture and laboratory observations, teacher and student interviews, and student journals, it is shown that it is possible for latecomers to science to engage in successful identity work in their science courses. However, the prevalence of the teacher-centred and sink-or-swim cultural models of learning in the figured world of the science program limited the resources available to latecomers to do so. This often resulted in them being positioned in the less powerful subject position of a good student, rather than good at, or interested in, science. The two cases suggest that the practices promoted by the concepts of active learning and social constructivist approaches to teaching and learning would help move away from these traditional cultural models of learning and towards a student-centred model. This would offer latecomers more resources with which to engage in successful identity work in their courses, thus affording their construction of inbound science

identity trajectories. Specific suggestions for teachers' practice and directions for future research are provided.

Latecomers are students who access postsecondary science through alternative routes, as opposed to entering directly from high school (Jackson & Seiler, 2013). They differ from traditional science students, in that, prior to postsecondary science, they followed a non-traditional sequence of courses and/or had a history of mixed academic achievement, that is, they received some low or failing grades in science-related courses. These differences from traditional students mean that they experience unique challenges to their persistence in postsecondary science (American College Testing, 2006; Jackson & Seiler, 2013). However, because latecomers to science are new to the science education research agenda, little is known about what these challenges are and how they can be overcome.

In a yearlong study of 18 latecomers to science, Jackson and Seiler (2013) found that the widespread cultural models that a good science student (a) achieves good grades and (b) follows a particular sequence of courses, referred to as the paradigmatic trail, significantly constrained latecomers' ability to identify with science, and only eight of the 18 latecomers persisted through their first year. The continuation of this research found that only 5 of the 18 persisted through to graduation from the science program at Island College, a rate well below the persistence rate of traditional students.[12] However, those five students are, at the time of writing this paper, all engaged in science-related careers and/or university programs, demonstrating that despite the

[12] Jackson and Seiler's study and the current study were situated in Island College, an Anglophone Québec Collège d'Enseignement Général et Professionnel (CEGEP). The role of CEGEPs in Québec postsecondary education will be described in the Methodology.

challenges, latecomers to science *can* successfully forge futures in science. This current study focuses on the experiences of such latecomers to science in the hopes that their successes can point to resources that can be helpful in affording fruitful identity work for latecomers to science.

Jackson and Seiler (2013) explored how latecomers made sense of their experiences in science to author themselves as moving towards or away from science. It was shown that latecomers had to improvise significantly with a variety of resources in order to find ways to identify with science that didn't rely on the dominant cultural models. Focusing on students' authorings of self rather than the day-to-day occurrences in their classes and other course-related activities, Jackson and Seiler were able to make recommendations for supporting latecomers at the program and institutional levels. In order to understand how course practices constrained or afforded latecomers' science identity trajectories, this paper explores how two successful latecomers from Jackson and Seiler's (2013) original study engaged in identity work in their courses.

In science education, researchers are increasingly relying on identity to understand how students learn and participate in science (Ardenghi & Jackson, in press; Shanahan, 2009). In postsecondary science, a number of studies have applied the lens of identity to students' persistence (e.g., Buck et al., 2006; Carlone & Johnson, 2007; Hunter et al., 2007; Johnson et al., 2011; Tate & Linn, 2005; Tonso, 2006). However, of all these studies, only Tonso observed students participating in their courses. The others relied largely on interview data and thus were unable to provide significant insight into how classroom practices contributed to the process of identity construction. Tonso's (2006) study documented powerful cultural forms of scientist and engineer that permeated the engineering campus community and constrained the ways in which students could identify within that community. Similar to Tonso's work, I explore how the possibilities for participation available within the various settings of latecomers' science courses (i.e., the available resources) both afford and constrain latecomers' ability to identify with science.

Theoretical Framework

The construction of identity is a useful theoretical concept allowing one to understand the individual as having some leeway in how they are recognized by self and others, while emphasizing that this is a process of negotiation, and thus the social world in which one participates and the resources that one is able to draw on to participate play an important role in how one is recognized. In this conceptualization of identity rooted in social practice, one's identification with science is continually under negotiation and may vary from one moment to the next. In keeping with this understanding, I use the more dynamic terms *identity work*, *identification* or *identify*, rather than the noun *identity*, which has connotations of being a possession one can carry across time and contexts (Brandt, 2008).

Positioning and Recognition

Identifying with science in a particular time and place is understood to be a social process of positioning and recognition, in which one draws on the available resources to bid to be recognized as a certain type of person (subject position). Davies and Harré (1990) explained that positioning can be interactive, in which what one person says positions another, or reflexive, in which one positions oneself, neither of which is necessarily an intentional act. Although Davies and Harré (1990) focused on the conversational aspect of positioning, positioning can also be accomplished in other ways, such as through one's actions (Gee, 2011b). However, as Carlone and Johnson (2007) emphasized, simply bidding to be recognized as a certain type of person is not sufficient for identification with science. One's bid must be recognized by others as credible, and the identification process is particularly powerful when that recognition comes from *meaningful* scientific others, such as one's teachers (Carlone & Johnson, 2007; Gonsalves, 2010). Here, powerful means that that the resources acquired in that interaction are likely to contribute to one's ability to identify with science in future interactions.

Figured Worlds and Resources

Holland, Lachicotte, Skinner, and Cain's (1998) use of *figured worlds* provides a framework for conceptualizing how the process of positioning and recognition is afforded and constrained by the context in which one is participating. It also provides an understanding of how individuals can still improvise with the resources at hand to position themselves in ways not necessarily afforded by the figured world in which they are participating. A figured world is a set of simplified stories and all the accompanying resources that *figure* (or construct) the world in a particular way. Holland et al. describe it as a "realm of interpretation," (Holland et al., 1998, p. 52) that captures what is taken to be typical in a given context (e.g., the Island College science program). Figured worlds value some forms of participation over others (Holland et al., 1998), meaning that certain subject positions are associated with success and increasing participation (e.g., a good science student) and tend to lead to positive recognition by meaningful others (e.g., teachers).

Through participation in activities organized by a particular figured world (e.g., as latecomers participate in the various settings of their science courses), actors acquire and learn to use resources that, unlike identity, they can carry with them across contexts and time. Here, the term resources is used to refer to anything that one can draw on to participate in social activity, including subject positions, practices, and, importantly, the mental/emotional knowledge structures, or cultural models, that are used to reinterpret and make sense of experience, and thus guide one's continued participation (Holland et al., 1998). Cultural models, like the figured worlds to which they contribute, exist on many scales. However, in this paper, as in Jackson and Seiler's (2013) previous study, it is the overarching cultural models that are reproduced within the various settings of the science courses of the pre-university science program that will be of the greatest interest.

Jackson and Seiler (2013) showed that latecomers' ability to increasingly identify with science was constrained by the dominance of two cultural models of the Island College science program: a good science student achieves good grades and a good science student follows the paradigmatic trail. This paper continues to explore the figured world of the Island College science program, examining how the resources made available in latecomers' science courses, in particular the cultural models of learning, afford or constrain latecomers' identity work in their courses, and thus their persistence in the program.

Identification over Time and Identity Trajectories

Because of the fleeting nature of identity, when one is concerned with longitudinal processes such as the persistence of latecomers, it is useful to also consider the concept of identity trajectories. As a latecomer participates in a series of science-related contexts, his or her sequence of identification with science forms a distinctive science identity trajectory that, over time, follows a recognizable trend. Drawing from Wenger (1998), Jackson and Seiler (2013) elaborated on three possible overall trends in latecomers' science identity trajectories: inbound, outbound, and peripheral. Inbound trajectories are characterized by an overall trend of increasing identification with science (regardless of smaller scale fluctuations), and thus support persistence in postsecondary science. In contrast, outbound trajectories are characterized by an overall trend of decreasing identification with science, and thus lead to the individual eventually switching out of the science program. Lastly, peripheral trajectories are characterized by a fluctuating pattern of identification and disidentification with science, resulting in an overall trend of unchanging identification with science that remains relatively near the dividing line between does and does not identify with science.

Such patterns in science identity trajectories arise because, over time, one acquires and uses resources that can assist or hinder future processes of identification. In other words, previous moments of identity work shape future identity work, leading to the formation of broad patterns in one's identification with science over time (Jackson & Seiler, 2013; Wortham, 2006). Particularly pertinent to the current study, are the ways in which latecomers' participation contributed to how their teachers positioned them in subsequent interactions, even in situations where the latecomer was not actually present. For example, if a teacher observes that a student is off-task during lecture, perhaps sleeping or texting, the teacher may position that student as being a lazy student in-the-moment. If that student later asks for an extension on an assignment, the teacher may not give it, positioning the student as undeserving of such allowances, which would contribute negatively to the student's construction of an inbound science identity trajectory. In this way, we can understand that latecomers' actions in their courses constitute identity work and have the potential to contribute significantly to their persistence in postsecondary science, particularly through interactions with their teachers.

Drawing from this theoretical framework, to gain more insight into latecomers' persistence in science, I ask the following research question: *What overarching cultural models are reproduced in the courses of the figured world of the science program and how do latecomers use the resources made available in their courses to advance their identity work towards science?*

Methodology

This study takes the form of two case studies (Yin, 2009) of Debbie and Jason, two latecomers to science who were successful in persisting through the Island College science program and on to university science. Following Debbie and Jason through their first year in the pre-university science program, a range of data is drawn on to explore how these two latecomers positioned themselves in their courses, how their teachers responded to their bids for recognition, and how such identity work contributed to their ability to construct inbound science identity trajectories. Data includes lecture and lab observations, teacher interviews, student interviews, and student journals. A full description of the data collected and its analysis is given in this section, but first I provide a description of where the Island College science program fits into the Québec educational context, along with an explanation of participant selection.

Context

The Island College science program. CEGEPs are public colleges that provide two-year pre-university programs, three-year career programs, and technical programs. Québec's tuition free CEGEPs provide a unique opportunity for research into issues contributing to student enrollment and persistence in postsecondary science without the obscuring influence of tuition fees.

In Québec, secondary school ends after Grade 11, after which students can attend CEGEP. The two-year CEGEP pre-university science program is comparable to 12th grade and first year of university in the rest of North America. In Québec high schools, students are streamed into advanced or regular science and math courses in Grade 10 depending on their marks.[13] To access a pre-university science program directly, students must earn at least 70% in

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[13] This process has changed slightly now, but it applied for the participants in this study.

the Grade 11 advanced math and science courses. If students are missing prerequisites, they may access the CEGEP *preparatory science program*, in which they have up to two semesters to complete make-up courses. If successful they will be accepted into the pre-university science program. These are the students I call latecomers to science. Although Jackson and Seiler (2013) used the term *science program* to refer to both the preparatory and the pre-university program, this paper focuses entirely on students' identity work in the pre-university science program and thus references to the science program in this paper refer specifically to the *pre-university science* program.

Participant selection: Debbie and Jason. Debbie and Jason were part of a group of six latecomers selected from the 18 latecomers tracked through their first two semesters of science at Island College (some of whom were in the preparatory program for both semesters and some of whom accessed the pre-university program in the second semester). These 18 latecomers were all students in a make-up physics course I taught at Island College in Fall semester of 2009. More information on this course and the corresponding research is given in Jackson and Seiler (2013). At the beginning of their second semester (Winter 2010), six latecomers were asked to participate in the next phase of the data collection, meaning they would be followed for another year, for a total of 18 months; all agreed. These six ongoing participants were selected because they had expressed on multiple occasions that they found the research interesting and enjoyed participating in the first phase.

Jason and Debbie were selected from the group of six ongoing research participants to be the two cases analyzed and presented in this paper for two reasons: (a) they were successful in persisting in the pre-university science program throughout and beyond that year, and (b) like the majority of latecomers to science, they had academic histories that varied significantly from the cultural models of good grades and the paradigmatic trail. None of the other four ongoing participants met these requirements as only one other persisted to graduation and she was an anomaly amongst the latecomers in that she quite closely fit the dominant cultural models of a good science student despite her latecomers status (a detailed analysis of her inbound trajectory can be found in Jackson and Seiler [2013]). A summary of Debbie and Jason's basic background information is given in Table 1.

Data Collection

As is necessary in case study methodology, this study draws on a wide variety of data sources to provide deeper insight into the complexity of latecomers' identification with science (Stake, 1995; Yin, 2009). A summary of all data collected from Debbie and Jason, as well as data used from the other six ongoing participants, is given in Table 2 and is elaborated on in the following.

Reflective journal entries via email were a part of the initial research project during the make-up physics course in Fall 2009, and the six ongoing participants continued to write these journals during the following year until either they left the program or the year ended. I responded to each student's journal entry, asking them to elaborate or clarify certain topics that arose, letting the student's reflections guide the topics explored. I also let participants guide how many journals they wrote in order to ensure I didn't overburden their workload. As requested, each journal included a discussion of their current courses (how they were feeling about them, anything that stood out or that they felt like sharing), as well as anything else that they wished to discuss. The six ongoing participants, including Debbie and Jason, also participated in approximately 1-hour, semi-structured, audio-recorded interviews at the end of Winter and Fall 2010 semesters. In these interviews, I asked the students about their experiences over the past semester, how it compared with previous semesters, how they felt about their upcoming semesters, what they were thinking about their future in science and in school, as well as anything that had arisen in their journal entries that seemed worth pursuing. As participants responded, other topics naturally arose, which they were encouraged to discuss. Only Debbie's and Jason's interviews were used in this paper.

For the four ongoing participants who persisted in science through the year of data collection, I also conducted observations for a 1.5-hour lecture and 2-hour lab in each science course approximately once per month per course in their third semester.[14] I also observed a few of all six participants' courses in the final month of second semester. Overlap in participants' courses was not uncommon. For example, Debbie and Jason took the same third semester math and physics lecture (although their physics labs were separate) and also had the same chemistry teacher, although their chemistry labs and lectures were at different times. Altogether I observed 34 lectures and 14 labs for a total of 79 hours of observation, 45.5 hours of which included Debbie and/or Jason (see Table 2 for a summary of Jason and Debbie's observations). During lecture observations, I always sat at a desk in the back of the classrooms, noting any interactions between each of the participants and their teachers, including body positions, actions, and any other relevant observations such as the layout of the room, contributions of other students and a summary of the teachers' lectures. The classroom sessions were recorded using a digital audio-recorder placed at the front of the room. I used much the same process during laboratory (lab) observations, except because it was mainly students working in groups at their station, I placed recorders at the stations of several different groups (to maintain the anonymity of my participants

[14] Throughout this paper, the term *science course/teacher* includes any math course/teacher taken by participants as part of the science program, as these courses are considered core courses.

as much as possible), and from time to time walked around to the different groups to observe exactly what they were working on.[15]

Semi-structured, audio-recorded interviews were conducted with each of Debbie and Jason's science teachers at the end of each semester as well as the teachers of the other students from the group of six who were still in the science program at each point in time. In the first half of these approximately 30-40 minute interviews, teachers were asked to discuss their understandings of latecomers to science, the challenges they see latecomers facing, and the challenges they see all science students facing, as well as to describe any strategies they use to help their students overcome these challenges and to describe their teaching style. In the second half of interview, teachers were told which students I was following and asked for their general impressions. A variety of topics emerged from their responses, but when it didn't come up spontaneously, teachers were always asked to describe their interactions with the student(s) and whether or not they felt the student would experiences difficulty continuing in science. In total, 20 teacher interviews were conducted, 12 of whom were teachers of Debbie and/or Jason. The data collection period concluded at the end of their third semester, (that is, the last teacher interviews conducted in Jan. 2011). Lastly, for context, final grades and class averages were collected for all courses taken during the entire 18 months they were enrolled in science at Island College (both preparatory program and pre-university program). These grades are listed in Table 3.

Data Analysis

In keeping with the research question, the data were analyzed for the ways in which Debbie and Jason positioned themselves and were positioned by their teachers in their science

[15] Consent was obtained from all students to be audio-recorded.

courses, focusing on the resources they used in their identity work, including the overarching cultural models that constrained the resources available. Before the analysis was conducted, all audio-recorded data were transcribed, with the exception of lab audio-recordings in which the students were interacting in groups with no teacher involvement. In these cases, the recordings were listened to in full and excerpts representative of the types of identity work that went on between peers were transcribed for analysis.

There were three settings in which students could engage in identity work in their courses: lecture, lab, and out-of-class (e.g., assessments and office hours). All 34 lecture observations and 14 lab observations were analyzed together to gain insight into the resources readily made available to latecomers in the settings of the lecture and lab. From this, general descriptions of the lectures and labs were written (presented in Findings section). It was relatively easy to generalize across courses, as most lectures and labs followed the same traditional formats. As part of these descriptions, the resources available for student participation (and thus identity work) were listed, as well as some resources that were noticeably not available. For example, it was observed that in lectures, students could choose where to sit in the room and thus seating location was an available resource, but desks were arranged in rows and thus working in a group was not an available resource. Similarly, interrupting the lecture to ask the teacher a question was an available resource, but engaging in a class discussion was not. When unique resources were observed, a note was made in the general description. For example, in one lecture the students were provided with markers and small whiteboards on which the teacher occasionally asked them to write their answer to a multiple choice question and hold them up. A short description was also written for out-of-class resources, namely office hours and assessment activities. These descriptions were drawn from a combination of teacher and student interview and journal data rather than observations, as well as insight from my position as an insider to the science program.

In order to gain a clearer picture of the overarching cultural models that shaped the resources available for participation in the courses and thus latecomers' identity work, Gee's (2011a) Figured Worlds Tool was applied to the generalized descriptions of the three course settings, all teacher interviews (not just Debbie and Jason's teachers), and the portions of all six ongoing participants' journal and interview data in which they spoke about their specific courses. This critical discourse analysis tool asked: What must the actor/speaker/author have assumed to be normal about the world in order to have acted/spoken/written in this way? By focusing on what was assumed to be normal about student and teacher participation in the courses, as well as how teachers and students spoke or wrote about what went on in the courses, I gained insight into the overarching cultural models, focusing on those unrelated to the dominant cultural models of grades and the paradigmatic trail already explored in depth by Jackson and Seiler (2013).

Debbie and Jason's transcribed observations, teacher interviews, and journals were then analyzed to gain insight into how they drew on the available resources to advance their identity work towards science. This was accomplished through an application of Gee's (2011a) Identities Building Tool, which asked the following of the data: What subject position(s) is the individual trying to enact or to get others to recognize? How is the individual positioning others? Asking these questions of the observations allowed an exploration of how the process of positioning and recognition unfolded in the moment, including how this process was constrained and/or afforded by the available resources. Asking these questions of the teacher interviews provided an understanding of how, over time, Debbie and Jason's repeated use of certain resources and the corresponding identity work resulted in their teachers learning to position them as moving towards science, thus affording their construction of inbound science identity trajectories. Lastly, asking these questions of the latecomers' journal and interview data not only provided further insight into the resources that Debbie and Jason drew on to participate in their courses (through self-report), but also provided insight into some of the cultural models they acquired outside of the figured world of science that helped guide their successful identity work in their courses. For example, I observed that in every lecture Debbie sat in the front row, suggesting that she was bidding to be recognized as an attentive science student. As mentioned, seating location was one of the resources readily available to students, while other resources for participation, such as actively doing and discussing science were not as readily available. There was no obvious recognition for Debbie's seating choice received in-the-moment from her teachers. However, in the teacher interviews, several of her teachers commented that she always sat in the front row and referred to her as a good student because of it, providing evidence that her use of seating location had been successful, in that her teachers positioned her as a good student, at least in part, because of it. Lastly, in her narratives, not only did Debbie report that she sat in the front row in lectures, she authored herself as someone who had been away from science for a while and therefore needed to do everything she could to succeed, including sitting in the front row. This evidenced that her understanding of herself as a mature and responsible latecomer afforded her successful identity work in her courses.

Findings

Divided into the three course settings (lecture, labs, and out-of-class), this section first provides a general description of each setting, then shows how these settings reproduced two overarching cultural models that greatly limited the available resources for student participation: a *teacher-centred* cultural model of learning and a *sink-or-swim* cultural model of learning. It is then shown how Debbie and Jason worked within the constraints of these cultural models, drawing on the available resources to engage in successful identity work in each setting. It is also shown how such instances of identity work sometimes contributed to their teachers learning to position them as moving towards (or occasionally away from) science across time and contexts, which had the power to greatly impact their identity trajectories.

Lectures

General description. All classes were lecture-based, 1.5 hours in length, and were sometimes referred to by students, and even more often by teachers, as *lectures* rather than *classes*, hence the use of this terminology throughout this paper. The teachers spent most, and often all, of the lecture at the front of the room, usually with a table between them and the first row of students, while the students were arrayed in rows at individual desks. Teachers generally presented PowerPoint slides, and/or notes projected from transparencies, and/or wrote on the chalkboard as they spoke, this last approach resulting in a significant amount of time with their back to the students. [16] When problem solving was part of the content, the teachers would usually present the problems and then immediately solve them themselves.

In most lectures, students were largely left to choose whether or not to pay attention, with little encouragement either way. Many teachers allowed students to sleep, play with their phones in class, and chat/whisper off-task provided the noise levels didn't exceed their personal tolerance levels, which varied widely. Most teachers never called on a specific student to answer a question, unless the student initiated such an interaction. This meant that students could, and

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[16] All such descriptions are generalizations and there were exceptions. For example, I attended one lecture where the teacher gave the students 15 minutes to work in groups on a challenging problem, while circulating the room. However the descriptions provided here reflect the large majority of lectures.

did, spend entire classes disengaged and off task with no obvious negative recognition from their teacher, unless they became disruptive, which was rare.

In many lectures there were only a handful of student contributions, each not more than a sentence or two, often less. In several observed lectures, there were no student contributions for the first half hour. In some lectures, the teacher made an effort to elicit contributions from their students, engaging them in triadic dialogue[17] as the teacher solved problems or wrote notes on the board/screen. In such cases, contributions tended to be dominated by the same few students per class, leaving the other 30-40 students to passively watch and listen. In other lectures, student contributions only occurred when a student would interrupt to ask a clarification question. This is not to say that the teachers explicitly discouraged students speaking up. Often, some students seemed perfectly comfortable interrupting the teacher or responding to their questions. When students did speak up, almost all teachers were pleasant and responded kindly, regardless of whether they were asking a pertinent question or not, or if they answered the teacher's question correctly or not. However, there was also little explicit encouragement for students to ask questions, with teachers usually only pausing every now and then to ask something along the lines of, "any questions?" and then moving on after a few seconds if there was, as was often the case, only silence in response.

Cultural models of learning. The format and set up of the lectures reproduced a *teacher-centred* cultural model of learning, in which the teacher was in control of what and how

[17] The term triadic dialogue was used by Lemke (1990) for a common form of teacher-student discourse in science classrooms, where the teacher asks a question, the student responds, and the teacher evaluates. This is often referred to as IRE (Initiate, Respond, Evaluate) and is used to designate science teaching that is teacher-centered and does not promote deep learning and conceptual understanding.

science was learned, and students were there to receive the teacher's knowledge. This greatly limited the latecomers' opportunities to position themselves in relation to science. The main resources available for participation in the lectures were to sit and listen or sit and not listen, take notes and follow along or don't, be silent or answer the teacher's questions, or interrupt and ask a question. If students were not comfortable speaking in front of the entire class, or questioning their teacher, the only options were to be quiet and pay attention, or to disengage.

The format and set up of the courses also reproduced a *sink-or-swim* cultural model of learning in which students were assumed to be fully responsible for their engagement in learning science and the teacher's responsibility was to present them the course content. This model was reproduced in lectures, where students were largely left on their own to decide whether or not to pay attention and/or contribute to the class, and overall whether to learn science or not. This same model of learning was evident throughout the teacher interviews, although some teachers expressed an understanding that it was detrimental to their students.

> I was lecturing and you know, some get it and some don't. But from my point of view, I was giving a lecture. It's up to you. There is still something in me that believes in it. But I have started to realize they need more than that. . . . . I just have to stop lecturing and I have to try to teach them.

Working with available resources.

Attentiveness. Debbie and Jason were both attentive in the lectures, that is they watched their teacher, took notes, and did not chat off task. Jason was almost always silent, made regular eye contact with his teacher and took notes when appropriate. Other than eye contact from the teacher, there was no observable recognition given to Jason for his behaviour of paying attention in class. However, every one of his teachers noticed that he paid attention and used this behaviour to position him as a good student in the teacher interviews. For example, one teacher used it to position him as a "really good student" despite his barely passing the course.[18]

Phoebe: To start with, I'd just like to get your impression of Jason.

Teacher:I thought he was a really good student. He came to class, paid attention, did work in class. Yeah.

Debbie also paid attention in class, perhaps even more overtly that Jason, never socializing with anyone around her, taking copious notes, often on her laptop, and watching the teacher closely. Unlike Jason, she further positioned herself as attentive by almost always sitting in the front row, often near the centre. Such a seating choice, along with her other attentive signalling behaviours, were recognized by all of her teachers in the interviews and were used to position her as a good student, like Jason. In an interview, one teacher described Debbie's classroom behaviour this way:

> She sits generally near the front, and near the projector and the computer. So she's put herself in a position of advantage I think. She usually has her laptop with her and she's working on her laptop, but I don't ever have any concerns that she's doing anything other than the school work. She's quiet. She doesn't ask a lot of questions in class. So yeah. I think she seems like a mature responsible student.

This type of behaviour was supported by Debbie's cultural model of herself as a better student than many other students, including herself in the past, due to her latecomer status. Drawing on her 2-year absence from science courses and her older age, she authored herself as a

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[18] To protect the anonymity of the participating teachers, wherever possible, as little information as possible is given about the teachers being quoted.

responsible and mature student who needed all the study tips she could get, and she actively sought out available resources for learning how to be a better science student. For example, she reported learning to always sit in the front from a study guide posted online by the science program. In this way, she used her latecomer status as well the study guide, as resources to advance her identity work in a figured world in which active involvement in one's learning was optional. In one journal entry, Debbie wrote:

> Because these kids [some of the other science students] think it's cool not to study and to do poorly . . . I don't really consider myself to be one of them, and I couldn't care less what they think. I think this has come from a combination of things. 95% of my friends being gone from the school . . . and being older than them.

Jason's narrated his attentiveness as largely guided by a cultural model of the nature of science that made science inherently interesting to him. Over the study period, Jason moved from understanding science as revealing underlying truths of the universe to science as being a social process of trying to make sense of our universe. He used this cultural model of the nature of science to author himself as finding science more interesting to him. Comparing himself to most other students he journaled, "the students that are just there for the mark aren't going to care about the profound significance of covalent bonding." This view of science, in turn, helped him make sense of how he could, and did, strategically participate more actively in his learning of science, as demonstrated in his following journal entry:

> If I'm interested, I'll learn things on my own, and if I learn things on my own and bring that knowledge to class then I'll learn new stuff more easily and keep my interest up. . . . So if I contain myself within interest, I should do okay.

How he acquired this deepening cultural model of the nature of science was not clear in the data, as the nature of science was not explicitly addressed in any of the courses (and such an understanding was not expressed by any other students who participated in the research), nor was it related to any of his complementary courses. However, Jason did often narrate himself as a philosophy hobbyist, suggesting that he was inclined to explore such avenues of thought outside of school.

Asking/answering questions. Debbie and Jason were both reported by themselves and their teachers as being quiet in lecture and rarely speaking up. Debbie narrated her silence in class as being related to a fear of being put on the spot and being unable to respond in an intelligent manner. “I have like this fear of being asked questions and it just ruins my concentration and it makes me feel really nervous” [Interview]. That this guided her silence in lecture is perhaps best illustrated by her self-reported visit to one of her first semester teachers who sometimes called on specific students to answer question, during which she asked this teacher to not call on her during class because it made her very uncomfortable.

Unlike Debbie, who I never heard speak in lecture, Jason spoke in the lecture a total of nine times in 13 observations, which was more than some students, but much less than the handful of students who would likely be recognized by their teachers as active contributors. Once he was called on by his teacher to answer a question, which he did hesitantly, but correctly;[19] twice he called out an answer (correctly) to a teacher’s question, but it was not acknowledged by the teacher. Three of the remaining six contributions were voluntary answers to questions asked by his teachers. Interestingly, the remaining three all came from the same

[19] As mentioned, calling on specific students to answer questions was very rare, but it did happen to Jason in this one observation.

lecture, when the teacher went off topic at the end of lecture to discuss viruses in more depth, which incited the interest of quite a few students as evidenced by a sudden increase in the number of students calling out answers and questions.[20] This is the only time I observed Jason ask a question during lecture.

Jason: [Teacher is lecturing on the human cold virus. Jason raises his hand and is called on a few seconds later] Is the ability for the immune system to like recognize a cold genetic?

Teacher: No. It doesn't recognize the DNA. It recognizes the proteins. [Looking directly at Jason]

Jason: Because like the first time you ever have a cold, it doesn’t recognize it at all, does it?

Teacher: No, of course. You don't have any protection. . . . But here's a good point, how come when you get over the cold, how come you get another cold, like next year you'll get a cold too? [Continues at length, frequently looking at Jason]

Here we can see that by going outside of his standard form of participation and asking a question, Jason garnered recognition in the form of the teacher (a) building from Jason’s question to make “a good point” to the class, and (b) giving Jason a lot of eye contact, signalling that he recognized Jason’s interest in this subject.

Another finding related to the ways in which Jason and Debbie were positioned and received recognition in lecture is the overall lack of a reference by their teachers in their

[20] In discussion with the teacher after lecture, he told me that this part of the lecture was off-topic but that the students seemed very interested so he went with it.

interviews to their ability to do science in relation to their class participation. With the exception of the few times Jason asked or answered questions (which didn't seem to play a large role in his overall positioning in lecture, as both he and his teachers reported him as being quiet), Debbie and Jason's teachers usually positioned them as good at doing school (e.g., does the work, pays attention, good student), but not necessarily as someone who is good at doing science. Science was always part of the context, and thus being positioned as a good student in the science classroom also imparts recognition as being a good science student, but such positionings lack the power that could result if they were recognized in the classroom as good at doing science.

Lastly, when the teachers referred to Debbie and Jason's quietness in class, they never positioned them negatively, rather it was usually couched in a description of other resources, such as their attentiveness, to position them positively. This suggests that contributing vocally in class was not an important part of figuring a good science student in the science program, further supporting the teacher-centred cultural model of learning emphasized in the lecture format.

Labs

General description. Of the 12 laboratory sessions (labs) observed, 10 took the traditional form of students following a set of instructions in their lab manual to identify known substances (e.g., in chemistry) or calculate known constants (e.g., in physics). In these standard labs, the teacher would give a brief lecture (anywhere from 5-30 minutes) at the beginning, while students sat at their lab bench/table with their group, which consisted of two to four students. Next the students would gather the required materials from a central station, then settle at their station to follow the lab instructions, step by step. The teacher would circulate the room, helping those who asked, and checking in on the others to ensure they didn't need help, but overall the students worked alone in their groups. Often one or two students would take charge in each group, deciding what needed to be done, while also doing much of the hands-on work themselves, while the other(s) acted as a back-up calculator, interjecting questions and suggestions here and there. In other groups, the students would split the work, with one doing the hands-on tasks (e.g., getting the materials, diluting solutions, using the titration equipment), while the others would interpret the instructions, enter data and perform the calculations. From time to time the teacher would get the entire class's attention to make an announcement such as what the value of a certain number should be, a change to the procedure, or where in the procedure the groups should be at that point in time.

The other two observed labs (called non-traditional labs in this paper) were different in form, offering students more opportunities to demonstrate their ability to engage in higher order thinking and/or more authentic science, thus giving them more ways to position themselves in relation to science. One was a problem-based learning physics lab (one of Jason's second semester classes), in which the groups of four had to predict where on the floor a metal ball would land when launched at a specific setting on a ballistics pendulum apparatus. At the end of the lab, the ball was launched and the group with the target closest to the landing spot earned 10/10 marks for the lab. The next closest two were 9/10 and 8/10 respectively, and the rest earned 7/10. Students were allowed to test the pendulum at other settings and could measure the apparatus and anything else they felt might help them make their prediction. The teacher took a background role, supporting students, but not guiding them towards a particular approach. The other non-traditional lab that was observed was Debbie's anatomy lab in which the students were dissecting fetal pigs. I observed the second session of this 2-part lab. Students had a list of organs to find and draw, but the directions were broad rather than detailed, and the students had a lot of time to explore the pig on their own.

Cultural models of learning. In comparison to the lectures, the traditional labs offered more resources for students to position themselves and be positioned in relation to science than the lectures. They were able to interact with their peers to talk about scientific topics and engage in scientific tasks such as measuring, setting up and using equipment, diagramming, graphing, calculating, error analysis, and lab report writing. However, these tasks were low level scientific activities, required little critical thinking, and evidenced little of the reasoning processes important to doing science. Accordingly, the structure of the labs reproduced an understanding of science as being about following instructions and validating the known, supporting a teacher-centred model of learning, where even when not talking, the teacher's voice was constantly present in the form of the detailed instructions.

The sink-or-swim cultural model of learning was less obvious in the labs than in lectures, as the teacher circulated offering help to all students. However, there was still little encouragement of students' active engagement in their own learning. It was left up to the students to decide whether to try to understand the science hidden behind the instructions or to just follow the instructions to get to the correct results. The constraint this exerted on students' ability to identify with science is illustrated in the conversation below, which took place at the end of the non-traditional pendulum lab described earlier.

Phoebe: So I'm curious, what do you think about this kind of lab, compared to the

Jason: Conventional kind?

Phoebe: The normal kind of lab, from your book. Which one do you prefer?

Girl 1: I like these [problem-based] ones, 'cause it's more group effort.

Girl 2: And I find that whatever we figure out is more likely to stick 'cause a lab we do following the book or whatever.

Girl 3: And it's more of a challenge cause the procedure isn't there.

Jason: Yeah the regular labs are more mundane cause you're just getting a bunch of data and putting it into a table, or data studio, which never works.

As illustrated in the above quote, non-traditional labs like the pendulum lab reproduced a more student-centred cultural model of learning. In such labs, students worked closely with their peers to investigate a problem or topic. Rather than being guided by detailed instructions, the students were free to choose the direction they wished to explore, even if it meant making mistakes.

Working with available resources. In the traditional labs, both Jason and Debbie actively worked with their teammates to get the lab done, puzzling out the myriad of problems that they encountered in trying to follow the lab instructions. In such interactions they tended to gain recognition from their peers as competent at following the instructions and performing the required tasks. The following exchange is representative of the types of peer interactions both Debbie and Jason regularly engaged in during the 2-hour labs.

Debbie: Ok. The thickness is this and the diameter of the wire is this, then we should be dividing the thickness by that, and that'll tell us, how many of this there are. Right?

Partner: Didn't you calculate that already? Isn't that one hundred and

Debbie: Yeah well there's 120 for the length but we have to know for the thickness.

Partner: Oh right ok.

However, such forms of competent participation didn't always result in significant positive recognition from their teachers. Opportunities to bid for positive recognition from their teachers in the labs occurred only a few times per lab because the teachers usually only came over when the students asked for help, and both Debbie and Jason rarely asked their teachers for help in the labs, preferring to exhaust all other possible options.

When Jason's group decided to ask for help, Jason usually took the lead and he didn't hesitate to push his teacher for more information until he felt he fully understood. Take for example, the following exchange that occurred when Jason signalled to the teacher that his group needed help.

Jason: How much buffer should we have on the top?

Teacher: Well what we're going to want to do now is we're going to wanna let the buffer go down to the top of the bed, so you can sort of just see the top of the beets. Cause we want to put our sample directly on the beets.

Jason: Ok, but aren't you not supposed to leave the beets like exposed?

Teacher: Very briefly, like just when you put your sample on is the only time, the rest of the time you keep them covered with water.

Jason: Ok. Alright.

From such instances, Jason's science teachers learned to position Jason's as engaged in and interested in science, regardless of his low grades, as shown in the following teacher interview.

Teacher: Jason is quiet but I quite liked him. Not the strongest student by any stretch, but he asked good questions in the lab and uh, he's very quiet. But he seemed fairly interested in it.

. . .

Phoebe: You said Jason seemed interested. What gave you that impression?

Teacher: Just the way we interact in the lab, you know? He was at a table with a couple of good students. And he, far more than the other two, was actually engaged in the lab.

It is worth emphasizing, however, that while such identity work did garner him important positive recognition from his teachers, such opportunities were few in number.

In contrast to Jason, Debbie was more reluctant to ask her teachers for help in lab, and when she or her group did, she often took a passive role, as demonstrated in the following lab exchange in which her partner called the teacher over.

Partner: When you're multiplying your initial volume, do you take the volume that you took out of the stock or just the whole volume of stock?

Teacher: The volume you're using. The volume you transferred.

Partner: Ok, the volume you transferred. Ok yeah, so it's five.

Debbie: Uhhhh, okay? [uncertain voice]

Teacher: I mean why did you spend so much time using the pipette? You need to know that volume.

Partner: Ok, exactly.

Teacher: Now why did you take five mils? It was suggested seven and twelve.

Partner: Ok. Well we already did it, so.

Teacher: It's ok. It was a suggestion. But I just want you to be aware of what you're doing. You don't have to do it my way. [teacher leaves]

Debbie: Oh, I'm so confused. So the second volume is what you take out?

Despite Debbie having been an equally active participant in the lab until this point, Debbie's partner does most of the talking while the teacher is present. Thus, although being competent in the lab and often taking a leadership role in her groups, Debbie's interactions with her teachers did not tend to result in significant positive recognition of her ability to do science. This was confirmed by the fact that, in the interviews, Debbie's teachers did not use her participation in labs to positively position her (with one exception, which will be discussed in reference to non-traditional labs). One teacher even used her participation in the labs to negatively position her in the interviews, showing how Debbie's fear of being put on the spot by her teachers combined with the structure of the lab in which conversations between teachers and students only happened when the student was experiencing difficulty did have a negative impact on how she was positioned in relation to science. This teacher described Debbie in this way:

Teacher: I feel she [Debbie] lacks some kind of confidence. You know? She doesn't handle certain situations well, I felt. Like she didn't like not going out of a certain comfort zone.

Phoebe: What kind of comfort zones, in class?

Teacher: Well like in the lab . . . whenever she lacked confidence about what she was doing, she would get kind of down on herself, even down on me I think. She just didn't like it.

In contrast to the traditional labs, the other two labs that were observed offered the students more ways of positioning themselves in relation to science. Rather than just following instructions and asking for help, students were free to choose their own ways of doing the science activities in these labs. This gave them more resources to position themselves as interested in, and engaged in, science. Debbie and Jason both took advantages of the opportunities provided and positioned themselves not only as capable of doing science, but also as interested and enthusiastic about science, and they were recognized as such by their teachers and peers in these labs.

Jason and the problem-based learning lab. In the problem-based learning lab, Jason was noticeably more engaged in and enthusiastic than in the traditional labs. The following is representative of Jason's peer and teacher interactions in the problem-based learning lab.

Jason: Ok, I'm pretty sure we need to find that. So we could find that. And then if

Girl 1: Wait, if we measure, yeah! And then we have the angle at which it goes.

Jason: Yeah. And then we have the triangle.

Girl 1: Yeah.

Jason: Yay!

Girl 2: But will she let us measure it?

Jason: I'm sure she will. [Goes up to teacher and asks if he can measure the arm of the pendulum. She says "yes," and he goes over to the apparatus and takes the measurement.]

In this lab, Jason approached his teacher at least six times, mostly to perform a measurement or to discuss an idea his group had. In doing so, Jason positioned himself as actively engaged in problem solving and doing science, rather than as being good at understanding instructions as in the standard labs. This positioning was recognized by his teacher as shown in the teacher interview about this non-traditional physics lab.

> He [Jason] was engaged in lab. . . So, really they were working super well in team. . . . Jason was able to ask me questions during the lab. But in class, rarely he asked questions.

Although some of his other teachers positioned him as engaged in labs, this teacher (who did several such problem-based labs, although I observed only one) was the only teacher who used Jason's teamwork to positively position him. This suggests that the problem-based labs did provide additional resources for positioning Jason as a good science student.

Debbie and the exploratory dissection lab. In the fetal pig dissection lab, Debbie demonstrated significant excitement and interest that I had never before, and never again, observed in her participation in her classes and labs. She was always the one wielding the scalpel and/or using her hands to poke around and find things of interest. The following transcription is representative of her participation in this lab.

Debbie: Can we take them [the kidneys] out!? It'd be so cool if we could take them out and cut it in half and see how similar it is to the other.

Girl 1: Oh, is it that?

Debbie: It's not a big deal if we just pull it out, right? Like what are they going to do? [starts removing a kidney]

. . .

Debbie: Let's cut it in half and see how similar it is.

Girl 2: You've officially torn a kidney out with your bare hands.

Debbie: Yeah! Like a repo man!

Girl 1: Keep it low in case it squirts.

Debbie: It's not going to squirt.

Girl 1: That's nasty. [laughing]

In such exchanges we can see that given the opportunity to act on her own initiative to experiment with things that interested her, Debbie was able to position herself, and was recognized by her group members, as a confident dissector with a genuine interest in biology. Debbie's very active engagement and recognition from her group members continued for almost two hours, showing how such exploratory labs can provide significant opportunity for identity work, thus contributing to latecomers' ability to construct inbound science identity trajectories.

In this particular lab session, Debbie's regular teacher was absent. However, when I described the lab during the course of the interview, she positioned Debbie as being good at and enthusiastic about dissecting, evidencing that Debbie's identity work in the labs was not only between herself and her group members, but also involved her teacher, thus having even more power to impact her identity trajectory.

Phoebe: I observed part of the fetal pig dissection.

Teacher: Mhm.

Phoebe: Which was really interesting. And she [Debbie] was right in there. She was the one doing all the cutting.

Teacher: Yeah. I'm sure she would have been, yeah. She was good with the heart, when we did the heart. She also enjoyed doing the sheep's brain. I didn't see any of the fetal pig, but I would imagine she would, she would have been wielding the scalpel for sure. [laughs] Yep.

Such positionings of Debbie as good at science in relation to these dissection labs, contrasted with the same teacher's positionings of Debbie when talking about her classroom participation, when the teacher positioned her as a good and attentive student, but not necessarily as good at, or enthusiastic about, science.

Out-of-Class

General description. Outside of lectures and laboratory sessions, two important contexts for positioning themselves and gaining recognition from their teachers were available to students. The first was through assessment activities, which provided an asynchronous form of positioning and recognition. Assessment took a few standard forms in the pre-university science program. All classes had 2-4 unit tests, a final exam, one project (usually a research paper) and, with the exception of math, any number of lab reports. Many teachers also gave quizzes and assigned homework questions (either online or handwritten). Assessment activities were not gathered as data in this study, but a few generalizations can be made from the teacher interviews and my insider position as a teacher at Island College. Most tests and final exams were a combination of multiple choice, short answer, and long answer, where in many courses the long answer is not so much explanation, as calculations. Biology final exams consisted of 100 multiple-choice questions. The second way in which students could engage in identity work with their teacher outside of class and lab time was through interactions during office hours or via email, during which students asked their teacher questions about course content or assessment rules (e.g., how an assignment was going to be marked). Teachers were required to have a minimum of six scheduled office hours per week, although some had more and some used an open door policy.

Cultural models of learning. The resources available for students to interact with their teachers outside of lectures and labs also reproduced the teacher-centred model of learning. The assessment activities were all teacher created and teacher evaluated, leaving no room for students to actively participate in assessing their own learning. Because I did not observe interactions during office hours, it is more difficult to make claims about the cultural model of learning they reproduced. However, the language teachers and participants used around office hours (e.g., “getting help,” “coming in for help,”) portrayed the office hours as being a place where students came to seek help with the course content from their teachers, thus supporting the teacher-centred model.

The existence of the sink-or-swim cultural model of learning was perhaps best evidenced through teachers’ and students’ approach to office hours. In the teacher interviews, the teachers emphasized that office hours were an important resource for student success, but they also reported that they didn’t usually actively encourage students to attend, even if they were struggling in the course. “Sometimes it’s a little bit sink or swim. . . . But I’m always here to help if they are interested in improving” [Teacher interview]. Such a sink or swim cultural model assumed that students who do not enact the valued form of participation (e.g., seeking help during office hours), either do not need to or do not want to participate in this way, as opposed to not knowing how to or being afraid to for fear of negative recognition, as was earlier shown to be the case for Debbie asking/answering questions in lecture and lab.

Working with available resources.

Assessment activities. Debbie was able to find a way to use her assessment activities to engage in identity work that wasn’t focused only on grades. Having completed two-years of CEGEP courses in social science, Debbie had excellent communication skills, which she drew on to positively position herself through her assessment activities, whenever possible.

> I know he [her teacher] liked my essay. . . .my whole plan was to make it good, so that at least this teacher would see that I’m not a complete idiot. He would see that, you know, I may not be good at physics but at least I can do something. [Interview 2]

Debbie's successful use of her communications skills was recognized by all her teachers, who, in the interviews, positively positioned her as having a unique skill relevant to succeeding in science. One teacher went so far as to position Debbie as having a future in science writing, telling of an instance when he told Debbie that, based on some of her explanatory assessment responses, he could see her "getting a job eventually helping write patents and things like that."

In contrast, Jason's teachers never referred to his participation in assessment activities, other than to sometimes report that he did his homework or to discuss his grades on tests. This suggests that in the figured world of the science program, assessment was seen mainly as a means to grades, rather than as an opportunity for students to develop a closer relationship with science.

Office hours. In keeping with her expressed fear of receiving negative recognition from her teachers, Debbie was hesitant to use her teachers' office hours, "I usually feel intimidated before going to see a teacher, and even while talking to a teacher, which is why I don't go to their offices more often" [J17]. However, when Debbie did trust her teachers not to negatively position her for her lack of understanding, she used their office hours frequently (with the exception of two courses in which she didn't feel she needed extra help). This garnered her positive recognition from those teachers as being a good student. "Debbie did fine, in my course. I think she, she worked hard. And she came whenever she had problems" [Teacher interview]. Attendance of office hours seemed to be an important resource for figuring a hardworking student, evidenced by the repeated proximity of teachers' referring to Debbie as working hard and as attending office hours. Also, because of Debbie's communication skills, her use of office hours not only afforded her positioning as a good, hardworking student, but also sometimes as someone who was good at talking science. In the interviews, two teachers whose office hours

Debbie utilized positioned Debbie as good at speaking about science. “I have to say that Debbie was quite articulate. You know, the concepts that I was asking her . . . she was answering them very beautifully.”

A particularly powerful example of how Debbie used her communication skills and her teachers’ office hours together to engage in important identity work emerged from her narratives in which she, on four different occasions, told a story in which she successfully argued with a teacher about her answer on a test question. While the resulting minor grade increase was in itself a form of recognition, the more important form seemed to be the teacher recognizing Debbie as being right, that is, as understanding the science concept being tested. Even two semesters after the actual event, Debbie still returned to this experience to author herself as able to succeed in science, thus highlighting the power of teacher recognition through assessments and office hours in supporting inbound identity trajectories. For example, in her final interview, Debbie again told the story,

> So I explained to him how I would do it. And I got to the right answer! [chuckles] Like my answer was right. He just didn’t agree ‘cause he thought that I’d wasted too much material. . . . He made a big apology and then he told the whole class that whoever answered it the way I did would get their mark changed. So a lot of people were happy I guess.

In contrast to Debbie, Jason almost never used his teachers’ office hours. It is more difficult to state the type of recognition this garnered from his teachers. There may have been a connection between Jason’s non-attendance of office hours and his teachers’ positioning of him as not working hard enough. Almost every one of Jason’s teachers expressed the opinion that he wasn’t working as hard as he could. “I think he just has to work harder, you know? I don’t know what his other activities are, if he's spread out too much? I don't know" [Teacher interview]. It was not clear on what the teachers based this positioning, as they usually reported him as working well in class and labs, he generally submitted his coursework on time, and they couldn't observe his study habits at home. It therefore seems plausible that they positioned Jason this way, in part, because he didn't attend office hours, particularly because a connection between office hours and hard work (in positive form) was apparent in Debbie's data.

However, other than this tentative connection, there was little evidence that Jason's non-attendance of office hours resulted in any negative recognition. For example, almost all of his teachers had to be specifically asked whether or not Jason used their office hours, and when they responded that he didn't, most didn't attach any obvious evaluative stance. Furthermore, one teacher, in a course in which Jason earned a very low grade, used his lack of seeking help outside of class to explicitly position him as learning independently, which had positive connotations. Altogether, the evidence suggests that in the figured world of the science program, using office hours was not an essential component of figuring who is and isn't a good science student.[21]

Identity Work and Identity Trajectories

As has been shown, through their various forms of participation in the lecture, labs, and other interactions with their teachers, Debbie and Jason, to some extent, positioned themselves as good students, hardworking, mature, responsible, and interested in and engaged in doing science.

[21] A gender difference in positioning in relation to attending office hours could be read into these findings but such a connection cannot be drawn from only two case studies without other supporting evidence. Also, one of the other six ongoing latecomer participants, Allie, never used her teachers' office hours but was always positioned as a good student. Her case, however, was different in that she better fit the dominant cultural models of a good science students (see Jackson & Seiler, 2013)

As they participated in these ways and took up these subject positions, over time their teachers also learned to position them in these ways, even when they earned low grades. In this way, "the sediment from past experiences" (Holland et al., 1998, p. 18) was carried forward in time, not just by the latecomers themselves, but also by their teachers, whose positioning of them had the power to greatly impact their science identity trajectories. The power that a teacher's positioning can have on a latecomer's trajectory, and thus the importance of a latecomer's ability to negotiate positive recognition through the semester, is illustrated in the following example of how Jason's inbound science identity trajectory was greatly afforded by his identity work in his chemistry lectures and labs throughout the semester.

Throughout second semester, Jason was failing chemistry and after the final exam had an overall failing mark of 59%. However, drawing on Jason's participation in class and labs over the semester to position Jason as having a future in science, his teacher raised his grade to 60%, a pass.[22] Although his teacher's recognition of his capability in science was expressed in the form of a grade, this action was shaped by the various ways in which Jason successfully positioned himself over the semester as interested in and capable of doing science, despite low grades, as illustrated in the following teacher interview:

Teacher: With Jason I just decided, it wasn't only the 59. It was kind of a decision that I think he should keep going. But if I could speak to him, I would tell him that he didn't do well on the test, or the final or whatever. And if he wants to do better, he has to work and to be more active about his success.

Phoebe: What makes you feel that he's capable?

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[22] Although such a practice was not rare, it was entirely at the teacher's discretion—some students' grades could be raised to pass from as low as 57%, while others with 59% might not have their grade raised.

Teacher:I don't know. He just looks more intelligent, when I talked to him the few, the only time I speak with him is in the lab.

. . . [a little later in the interview, when discussing Jason's participation in lecture]

Teacher: I think he's listening to me. He's quiet, but he's not quiet looking at the ceiling or texting. No! He's quiet and looking at the board or at me.

Some of the impact this decision had on Jason's trajectory is obvious. Failing would have set him back another course, thus further disaligning him from the paradigmatic trail. Such disalignment is particularly detrimental for latecomers whose fragile trajectories are more vulnerable to the forces exerted during the processes of positioning and recognition (Jackson & Seiler, 2013). Jason discussed the damage such disalignment with the paradigmatic trail could do in his final interview.

Phoebe: What do you think it would feel like if you didn't pass a class?

Jason: Yeah. Well I would have to do another semester then. For sure. . . . I dunno. Cause my parents would have been, maybe pressuring me to change programs at that point.

Phoebe: Oh yeah?

Jason: They're like ok, well you were in [the preparatory program], and now you've failed something, maybe, you should rethink this. But, if that didn't happen, they'd just let me do my thing.

The repercussions of this positive recognition on Jason's identity trajectory reached even further. Throughout the next semester, Jason drew on this experience to explicitly author himself as moving towards science, as illustrated in his following journal excerpt:

> And I think the real [moment I felt like I belonged in science] was when I got my exam marks back for this semester. And I passed [chemistry] [chuckles]. I'm like, ok I could actually do this now. And as long as I, I like work throughout the year, I think I could actually realistically do well. So I think that's when I felt a belonging.

Even during the following semester, when Jason was again receiving a failing grade in his next chemistry course, he was able to draw on this past experience to project success, thus further affording his inbound science identity trajectory and helping him persevere. In the end he passed the course with a grade that was below average but well above failing.

Discussion and Implications

This study provides evidence that the *teacher-centred* and *sink-or-swim* cultural models of learning that dominated the three settings of the figured world of the science program in which students interacted with their teachers constrained the ways Debbie and Jason could and did position themselves in their courses in relation to science. The available resources afforded students taking a passive role in their learning of science: sitting quietly and listening in class, following instructions during labs, and doing the assigned work. Such passive forms of participation resulted in Debbie and Jason positioning themselves and being positioned as good students, but didn't afford their ability to position themselves more closely to science, for example as being interested in science, or being good at doing or talking science. Debbie and Jason were both able, in different ways, to sometimes successfully take up these more powerful subject positions, and doing so had positive implications for their construction of inbound science identity trajectories, supporting their persistence. However, such identity work tended to require them to draw on resources learned from other figured worlds (e.g., Debbie's language skills and Jason's cultural model of the nature of science).

To support students such as Debbie and Jason, more opportunities are needed to afford students' *active* engagement in the learning of science, particularly in the case of latecomers to science, whose science identity trajectories are inherently fragile and thus have more to gain or lose from identity work in their courses. Such opportunities would provide needed resources for their identity work. To this end, drawing from the cases of Debbie and Jason, several specific directions for teaching practice are suggested.[23]

First, however, it is important to point out that any such changes in practice can only work if accompanied by appropriate support for faculty (DeHaan, 2005; Handelsman et al., 2004; Wieman, 2007). The findings of this study show that it is not only a few simple changes in teaching practice that are needed, but a shift to an entirely different knowledge structure about student learning, moving from the teacher-centred, sink-or-swim cultural models of learning to a student-centred, active learning cultural model. Without this shift, any changes in practices are unlikely to succeed in their goal of supporting students' active engagement in their own learning (Bencze, Bowen, & Alsop, 2006). Accordingly, support in the form of professional development and physical and virtual resources (particularly time), as well as opportunities to reflect, assess, and adjust in the cyclical process of action research (Hinchey, 2008) are essential to the plausibility of such an endeavour succeeding.

[23] Although this manuscript documents the challenges that teacher-centred pedagogy presents to latecomers, it is not the author's intention to judge the teachers who participated in this research or to make claims about the quality of their teaching. They are all recognized by students and colleagues as being devoted and caring professionals. Rather, this research recognizes that the overarching cultural models that are reproduced in the figured world of the science program constrain not only latecomers' identification, but also teachers' practices.

Teacher as Co-Constructor

Debbie's case illustrates how latecomers' ability to engage in useful identity work with their teachers can be constrained when possibilities for interactions between teachers and students place the student at risk of being recognized as not understanding something. It is also reasonable to assume that not seeking help from certain teachers constrained Debbie's academic performance, again exerting a negative force on her science identity trajectory. To better support latecomers like Debbie, more opportunities could be made for interactions with their teachers in which the teachers are not figured as having all the answers and thus as always serving an evaluative role, but instead are figured as co-constructors of knowledge.

Such a social constructivist approach to teacher-student interactions can be initiated in many ways, all of which would include reducing the emphasis on lectures, where teachers have most of the power, and providing more opportunities for students to engage in science-related dialogue with teacher and peers, such as group and full-class discussions, debates, teamwork, and peer teaching. Most simply, as suggested by Debbie's case, the teacher-as-evaluator figuring could be reduced if teachers not only helped students when things were going wrong, but interacted with them when things were going well, in particular, during lab sessions. This would give the students the chance to position themselves, and be recognized, as competent science do-ers, an important aspect of identity work in science (Carlone & Johnson, 2007).

Incorporating forms of self and peer assessment can also go a long way towards dismantling the dominant figuring of teacher-as-evaluator, and serve to get all students, not just latecomers like Debbie, more engaged in their own learning of science. A more all-encompassing social constructivist approach was successfully trialed by Tsaushu et al. (2012), in which lecture was largely replaced by group independent learning sessions and group presentations/feedback sessions. Academically, the test results on recall/rote questions were unchanged compared to traditional teacher-centred courses, and performance on critical thinking questions was significantly improved. A similar approach would not be overly difficult to implement in Island College science programs, where student numbers do not exceed 50 students per class.

Encouraging Interest

Jason's case illustrates how developing an interest in science was a useful resource for engaging in successful identity work in lectures and labs. However, encouraging interest in science was not a focus of the teacher-centred and sink-or-swim models of learning. Instead, as shown, such understandings of learning assumed that students were either already interested or didn't belong in science. Refuting this assumption, Jackson and Seiler (2013) showed that latecomers to science can struggle with acquiring resources to support their interest as they are only beginning their foray into science. Together, this suggests that working towards helping students develop an interest in science in individual courses would better afford latecomers' ability to engage in successful identity work in class, contributing to their construction of an inbound science identity trajectory.

One means of supporting students' interest was suggested when Jason asked his teacher a question during class. In this particular instance, the teacher had strayed from his planned lecture to delve more deeply into the concept of viruses, which he realized was sparking his students' interest. This resulted in a flurry of questions from his students, including one from Jason, each of which sent the teacher deeper into the topic of viruses. Question asking by students has been shown to be a highly effective resource for increasing students interest, enthusiasm, and engagement in their own learning (e.g., Teixeira-Dias, de Jesus, de Souza, & Watts, 2005). This suggests that by letting students' interest guide them as to when and where to delve more deeply into topics, teachers can help all students engage more actively in learning. Such an approach favours depth over breadth, which can be controversial in pre-university programs such as the Island College science program, where teachers feel pressure to ensure they cover all the material their students may need in university. However, Schwartz, Sadler, Sonnert, and Tai (2009) showed that favouring breadth over depth does *not* better prepare science students for university, and in fact, reducing coverage to focus on at least one topic in great depth, actually improves students' academic performance in future postsecondary science courses.

Another means for supporting interest and thus students' active engagement in learning science was suggested by the success of the non-traditional, more open-ended labs. In these labs, Debbie and Jason had more opportunities to be engaged and demonstrably interested in what they were learning. This afforded successful identity work that ultimately resulted in their teachers learning to position them positively in relation to *science*, rather than just as good students. It is therefore suggested that latecomers' identification with science would be better supported by a reduction in the step-by-step approach to labs and more emphasis on the problem solving and exploratory nature of science. Such a suggestion is supported by research such as that by Teixeira-Dias et al. (2005), who, in successfully implementing such an active learning approach to first-year university chemistry labs (approximately equivalent level to Island College), explained that,

> It is important that laboratory work dispenses with long and complex lists of procedures with elaborate equipment, and must be based on fairly straightforward ideas and require simple equipment, easily available in the laboratory. It is also important that laboratory

> work provides significant opportunities for students to really engage with the topics at hand. (p. 1129)

Nurturing Students' Unique Resources

Debbie's use of her latecomer status (e.g., her understanding of herself as a mature student and also her communication skills developed in her previous program) as a resource for advancing her science identity work, as well as Jason's possible use of his philosophy hobby to connect science more closely to his life, demonstrates that latecomers, like all students, already have unique resources that can afford their construction of inbound science identity trajectories. By encouraging latecomers to understand what these assets are and how they can support their progress in science, teachers could better support their persistence. This could be begun by providing more types of activities that foster and recognize a wider range of talents. The literature on multiple intelligences has explored such an approach to learning in depth, coming to the conclusion that to foster students' unique assets, teaching approaches must incorporate a variety of methodologies, where lecturing and laboratory sessions are but two of many others, such as discussion, case studies, visual representations, and even games (B. F. Brandt, 2000). For example, Shanahan and Nieswandt (2011) suggested that the incorporation of more creativity in school science (e.g., less instructions during labs and more opportunities for students to design their own experiments) would make science more available to a diverse range of students, while supporting a more realistic understanding of the nature of science, which is, despite how it is presented in school, inherently creative.

Active Learning and Identification with Science

In the preceding, I have suggested some ways in which latecomers' active engagement in learning science can be supported, focusing on the resources that were most or least supportive to

Debbie and/or Jason's identification with science in their courses. All of these suggestions are related in that they are forms of *active learning*, moving away from teacher-centred and sink-or-swim cultural models and towards a student-centred cultural model of learning. Active learning is a broad term applied to a variety of student-centred learning approaches in which the students are not only involved in physically doing things, but are involved in thinking about and making sense of what they are doing (Bonwell & Eison, 1991). There is already a significant body of literature on both the importance of supporting, and how to support, students' active engagement in science through *active learning*. Although the majority of this research is focused at the high school level and below, it is becoming increasingly popular in postsecondary science settings, where traditional teacher-centred approaches to learning are still the norm (e.g., Becvar, Dreyfuss, Flores, & Dickson, 2008; Braxton, Milem, & Sullivan, 2000; DeHaan, 2005; Salamonson, Andrew, & Everett, 2009; Schrire, 2006; Whetton, 2007). Such research has shown that active learning can result in deeper learning and better academic results for students, while also encouraging an increase in interest and engagement in learning science (e.g., Teixeira-Dias et al., 2005; Tsaushu et al., 2012). Braxton et al. (2000) even showed that active learning practices can support students' persistence in postsecondary education.

However, by considering the identity work that takes place in the postsecondary science classroom, the current study adds a new dimension to our understanding of active learning in postsecondary education and in science education. In particular, viewing the science program as a figured world allowed exploration into how the dominant cultural models of learning were reproduced by, and reproduced, particular resources for latecomers' participation in their science courses. This framework provided insight into how, the teacher-centered and sink-or-swim cultural models of learning that so often prevail in postsecondary science education, serve to largely constrain the extent to which students can engage in powerful identity work in their courses. This is particularly important for latecomers to science, such as Debbie and Jason, whose science identity trajectories have little momentum to sustain them through difficult periods (Jackson & Seiler, 2013). The significant impact that latecomers' identity work in their courses, in particular with their teachers, can have on their identity trajectories was highlighted by Jason's case. In this instance, his successful identity work in labs and in class resulted in his passing a course he would otherwise have failed, which had far reaching implications for his own ability to author himself as moving towards science. Although the importance of identity work in the classroom for marginalized students has been demonstrated time and time again in K-12 studies of science classrooms, it has been largely ignored in the higher education science education literature, despite it being implicitly acknowledged for many years.

> Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, apply it to their daily lives. They must make what they learn part of themselves. (Chickering & Gamson, 1987, p. 3)

Conclusion

This paper has shown that it was possible for latecomers to science to engage in successful identity work in their science courses. However, the prevalence of the teacher-centred and sink-or-swim cultural models of learning in the figured world of the science program constrained the resources available to them to do so, and often resulted in them being positioned in the less powerful subject positions of a good student, rather than good at, or interested in, science. This corroborates Jackson and Seiler's (2013) finding that, due to latecomers' differences from traditional science students, namely their histories of mixed academic success and/or alternative pathways into and through postsecondary science, more resources are needed to support latecomers' identification with science. Further exploring what types of resources can provide this type of support, Debbie and Jason's cases suggest that the practices promoted by the concepts of active learning and social constructivist approaches to teaching and learning would help move away from these traditional cultural models of learning, towards a student-centred model. This would offer latecomers more resources with which to engage in successful science identity work in their courses, thus affording their construction of inbound science identity trajectories and persistence.

Although the usefulness of active learning and social constructivist cultural models of learning in postsecondary science is not a new finding, as these approaches are, in fact, gaining ground in both research and practice, this study offered new insights into why such approaches are important. As the numbers of students following non-traditional routes through postsecondary education continues to rise (Goldrick-Rab et al., 2007), it is increasingly important that research into how to better support latecomers to science be continued. Building from the current findings, such research could implement and/or study latecomers' participation in figured worlds that are shaped by student-centred cultural models of learning science in order to further understand how the resources that shape and are shaped by such cultural models can better afford latecomers' identification with, and persistence in, science.

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Table 1: Background information on Debbie and Jason.

	Debbie	Jason
Age at start of preparatory science program (Fall 2009)	19.5	18
Gender	Female	Male
Ancestry	6th generation Canadian, ancestry from Ireland and France.	1st generation Canadian, parents emigrated from Greece before his birth.
Language(s)	English and French	English (secondary: Greek and French)
Science-related schooling leading up to accessing Island College pre-university science program	– Enrolled in advanced stream through high school – Failed Grade 12 physics and scored below 70% in math and chemistry – Applied to double major in social science and science at Island College directly out of high school but was accepted only into social science. – Took 2-years of social science in which she failed 8/23 courses. – Applied and was accepted into preparatory science program at Island College for Fall 2009. – Passed all make-up courses in first semester of preparatory program and was accepted into pre-university program for Winter 2010.	– Enrolled in advanced stream in Grade 10 but scored below his private school's 75% cut-off for access to the Grade 11 science stream in math. – Placed in regular stream in Grade 11 therefore could not take any science courses. – Applied and was accepted into preparatory science program at Island College directly out of high school for Fall 2009. – Passed all make-up courses in first semester of preparatory program and was accepted into pre-university program for Winter 2010.
Career goal at start of science program	Veterinary	Architect
Career goal at end of science program	Uncertain – animal biology related	Uncertain – physics related

Table 2: Summary of collected data for Debbie and Jason.
Observations and teacher interviews that overlapped for Debbie and Jason are listed for each (marked with an *). Extra data from other participants does not include overlapping data (i.e. courses that participants shared with Debbie or Jason or each other).

	Winter Semester Jan.–May 2010	**Summer Semester Jun.–Aug. 2010**	**Fall Semester Aug. –Jan. 2010**	**Summary Aug. 2009-Jan. 2010**
Jason	• 4 journals • 1 student interview • all final grades • 3 observations – 2 physics classes (3h) / 1 lab (2h) • 2 teacher interviews – physics/chem – (missing math)	• 1 journal • final grade	• 4 journals • 1 student interview • all final grades • 15 observations – 2 physics classes (3h)* / 2 labs (4h) – 3 chem. classes (4.5h)* / 1 lab (3h) – 2 bio. classes (3h) / 1 lab (2h) – 4 math classes (6h)* • 4 teacher interviews – physics*/chem*/bio/math*	• 9 journals • 2 student interviews • all final grades • 18 observations (29.5 hours) • 8 teacher interviews • 1 background data form
Debbie	• 10 journals • 1 student interview • all final grades • 4 observations ○ 1 physics class (1.5h) ○ 2 chem. classes (3h) ○ 1 bio. class (1.5h) • 4 teacher interviews – physics/chem/bio/math	• 1 journal • final grade	• 5 journals • 1 student interview • all final grades • 15 observations – 2 physics classes (3h)* / 2 labs (4h) – 3 chem. classes (4.5h) / 1 lab (2h) – 2 bio. classes (3h) / 1 lab (2h) – 4 math classes (6h)* • 4 teacher interviews – physics*/chem*/bio/math*	• 16 journals • 2 student interviews • all final grades • 19 obs. (30.5 hours) • 8 teacher interviews • 1 background data form
Extra data from other 4 participants	• 16 journals • 4 student interviews • 6 observations (including 1 lab) • 4 teacher interviews		• 4 journals • 2 student interviews • 11 observations (including 2 labs) • 3 teacher interviews	• 20 journals • 6 student interviews • 17 observations (27 hours) • 7 teacher interview

Table 3: Summary of final grades and courses taken in first 18 months in science at Island College. Dark font indicates core courses and light font indicates complementary courses.

JASON				DEBBIE			
Fall 2009		**Final Grade**	**Class average**	**Fall 2009**		**Final Grade**	**Class average**
1	Make-up Math	82	70	1	Math Bridging	76	74
2	Make-up Chemistry	75	62	2	Chemistry Bridging	88	70
3	Make-up Physics	82	74	3	Make-up Physics	90	74
4	Study Skills	80	77	4	French Level 4	80	77
5	Dark Fiction	85	80	5	Literary Genres	68	79
6	Fitness Conditioning	83	82				
Winter 2010				**Winter 2010**			
1	Calculus I	61	62	1	Calculus I	60	62
2	Chemistry I	60	59	2	Chemistry I	77	59
3	Physics I	76	65	3	Physics I	72	65
4	La Condition Feminine	78	74	4	Biology I	65	65
5	Jazz Literature	82	72	5	Forensic Anthropology	82	75
6	Martial Arts	93	87	6	Intro to Psychology	94	83
7	Cinema & Ideologies	90	74				
Summer 2010				**Summer 2010**			
1	Calculus II	72	75	1	Calculus II	69	69
Fall 2010				**Fall 2010**			
1	Linear Algebra	63	68	1	Linear Algebra	70	68
2	Chemistry II	67	69	2	Physics II	60	66
3	Physics II	71	66	3	Chemistry II	76	69
4	Biology I	72	71	4	Human Anatomy	77	73
5	Graphics Programming/Flash	80	85	5	Ethics for College Students	87	76
6	Views on Order & Freedom	90	75				
7	Thunder & Lightning	96	85				

Preface to Chapter 4

Chapter 2 showed how latecomers' ability to increasingly author themselves as moving towards science, and thus persist, was greatly constrained by the science program's dominant cultural models that figured a good science student as someone who gets good grades and follows the paradigmatic trail through high school and into and through college. Chapter 2 therefore concluded that latecomers would benefit from more exposure to resources for affording identification with science outside of these dominant cultural models of who can do science.

Next, Chapter 3 explored the resources for identification with science made available within the courses of the science program and how two latecomers were able (or not) to draw on these resources to receive positive recognition from their teachers. This chapter showed that, although it was possible for latecomers to engage in successful identity work in their science courses, the prevalence of the teacher-centred and sink-or-swim cultural models of learning greatly constrained their ability to do so, and in many instances resulted in them being positioned in the less powerful subject position of a good student, rather than being good at doing, or interested in, science. Supporting and extending the findings and recommendations of Chapter 2, Chapter 3 argued that the practices promoted by the concepts of active learning and social constructivist approaches to teaching and learning would help move away from these traditional cultural models of learning and towards a student-centred model. This would offer latecomers more resources with which to engage in successful identity work in their courses, affording their construction of inbound science identity trajectories, and thus their persistence.

Another important finding of both Chapters 2 and 3 was that latecomers often improvised with the available resources to try to overcome some of the constraints exerted by the dominant cultural models. In particular, Chapter 3 showed that latecomers such as Debbie and Jason entered the science program having already acquired resources from other figured worlds that, with some improvisation, had the potential to afford their identification with science. These findings suggest that one way to make available a wider array of resources may be to provide latecomers with opportunities to construct their own resources for identification with science. The online forums from the first semester of data collection were included in the make-up physics course precisely for this reason.[24] Online forums have been shown to offer a third space (Bhabha, 1994), that is, they increase opportunities for participants to import resources from figured worlds other than school science and/or (co-)produce new resources to help them identify with science. This is in contrast to in-class interactions where the available resources are strictly limited, as was clearly illustrated in Chapter 3. Building on the findings of the preceding two chapters, Chapter 4 returns to the online forums from first semester in order to explore the possibility of liberation from some of the constraints of the figured world of the science program through the co-construction of new resources.

This third and final approach to exploring latecomers' identification in science critically analyzes one thread of an online forum in which four latecomers co-constructed new resources to make sense of their differences from traditional science students, namely their academic struggles. It asks the research question: how do latecomers with histories of being recognized as not smart enough to do science, use resources to identify with science in an online forum? Despite its micro-scale analysis, Chapter 4 still examines the constraints of the figured world

[24] This aspect of the online forums was not initially a focus of the overall case study presented in this dissertation, but rather was just one facet of the initial action research project which later grew into this larger case study of latecomers' identification with science

within which latecomers must work, thus continuing to contribute to an increasing understanding of the figured world of the science program.

Chapter 4: I Am Smart Enough to Study Postsecondary Science: A Critical Discourse Analysis of Latecomers' Identity Construction in an Online Forum

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Abstract

The overall goal of this research is to better understand the persistence of postsecondary science students who are initially missing prerequisites (latecomers to science). This critical discourse analysis of an online forum thread uses Gee's (2011a) toolkit to explore how latecomers, who have histories of not being recognized as smart enough to do science, are able to identify with science. Applying a theoretical lens in which identity is viewed as a process of continual negotiation, which is constrained and afforded by the resources of the relevant figured worlds, it is shown how four latecomers shared reinterpreted histories of being recognized as not smart enough to do science and in doing so, formed solidarity. As part of this process they co-produced a new cultural model in which the ability or inability to ask questions led respectively to success (good grades) or failure (low grades) in science. Used in conjunction with their solidarity, they were able to not only successfully position themselves in the elite figured world of science, but to reify the result in a form that could potentially support future identification with science. Aspects of the online forum that supported the co-production are explored and implications for theory and practice, as well as future research, are given.

Compared to traditional science students, students who access postsecondary science through non-traditional routes because they are missing prerequisites, *latecomers to science*, are less likely to persist in their program (American College Testing, 2006; Jackson & Seiler, 2013). Despite global and national imperatives to increase persistence in science, there has been little research exploring how to support latecomers to succeed in their postsecondary programs (Mueller, 2008). Like other minorities, these overlooked students exist largely on the margins of science, hindered by histories of mixed academic success and educational paths that greatly differ from the traditional science student (Jackson & Seiler, 2013). As Joseph (2010) pointed out, "it is for those at the margins that identities matter most" (p. 17). Unfortunately, for many latecomers, regular experiences of disidentification with science are the norm (Jackson & Seiler, 2013). Nevertheless, they have resisted being kept outside of science. Fighting against disidentification, latecomers have forged a trajectory towards science to the point where they have accessed a postsecondary science program. Once in the program, however, persistence often becomes even more difficult. Jackson and Seiler (2013) found that in a cohort of 18 latecomers to science, only 8 persisted beyond their first year of a pre-university college science program, and only 5 persisted to graduation.[25] Thus, the overarching goal of this research is to better understand, and ultimately support, latecomers' persistence in postsecondary science.[26]

Latecomers to science often have a history of mixed academic achievement, meaning they have, on occasion, received low or failing grades. In education, academic achievement is

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[25] This last set of numbers (6/18) is the latest results from the ongoing project whose initial findings were first reported by Jackson and Seiler (2013).

[26] In reference to the process of identification and labelling of figured worlds, the terms *science* and *school science* are used interchangeably, as students' experience with science are largely school related.

commonly equated with an individual's possession of the stable, trait-like characteristic known as academic ability, intelligence, or being smart (Breen & Lindsay, 2002; Hatt, 2012). Accordingly, many latecomers have a history of being recognized, by educational institutions, their teachers, themselves, and others, as not smart enough to succeed in science. However, their postsecondary field of choice, science, is considered the most elite of academic disciplines, reserved only for the smartest students (Hannover & Kessels, 2004; Hughes, 2001; Olitsky, 2007). The prevailing discourse around the eliteness of science allows those students who have repeatedly been recognized as smart through consistent achievement of good grades, to easily identify with science. It even generates a sense of pride and solidarity amongst such students (Olitsky, 2007). However, the construction of science as elite tends to have the opposite effect for latecomers, whose history of mixed academic achievement makes it difficult for them to identify with science (Jackson & Seiler, 2013). It is therefore important for latecomers to find alternative ways to identify with science.

Jackson and Seiler (2013) argued that in order to identify with science despite histories of mixed academic success, latecomers need access to a wider range of resources. They suggested that the use of hybrid spaces, such as online forums, can afford cultural production of resources that can help latecomers' identify with science. Through the detailed analysis of an online conversation in which latecomers discuss histories of being recognized as not smart enough to do science, this paper explores the potential of an online forum to support latecomers' identification with science in a make-up physics course at Island College, an Anglophone Québec Collège d'Enseignement Général et Professionnel (CEGEP).[27] Keeping in mind the overall goal of better understanding latecomer's persistence, this paper addresses the following research question:

[27] All identifying names of schools and students have been changed to protect anonymity.

How do latecomers, with histories of being recognized as not smart enough to do science, use resources to identify with science in an online forum?

Theoretical Framework

In this study, identity is viewed as a continual process of identification, where individuals do not possess identities. Rather, individuals are constantly negotiating to be identified as a certain type of person in social interactions (C. Brandt, 2008). Within every context, there are socially recognizable ways of being, heretofore referred to as subject positions (Holland et al., 1998). Individuals draw on available resources to participate in certain ways in order to attempt to take up subject positions, and in doing so, make bids for identification as certain types of people, such as members of a particular community (Gee, 2000). The construction of identity is shaped by how others recognize and respond to such bids. Similarly, in some situations, the process is less about how the individual bids are recognized, and more about how others position an individual and in turn, how the individual responds to these imposed subject positions. Thus, identification is a continual negotiation between individuals and social contexts (Davies, 1989; Gee, 2000; Holland et al., 1998).

Figured worlds and Resources

The concept of figured worlds provides an understanding of how identification processes shape and are shaped by social structures, while remaining open to the possibility of change. A figured world is "a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (Holland et al., 1998, p. 52). Figured worlds "supply the contexts of meaning for actions, … for the understandings that people come to make of themselves, and for the capabilities that people develop to direct their own behavior in these worlds" (Holland et al., 1998, p. 60).

Figured worlds do not exist independently of people, nor are they carried around in our heads. Rather, a figured world is continually reproduced by our use of the resources that we acquire as we participate in activities organized by that figured world (Holland et al., 1998). These resources can take the form of cultural models, which are "mental/emotional knowledge structures" (Holland et al., 1998, p. 297) that help individuals *reframe* past experiences in order to position themselves and others within the figured world. Holland et al. explained that, "one's history-in-person is the sediment from past experiences upon which one improvises, using the cultural resources available, in response to the subject positions afforded one in the present" (p. 18). This means that latecomers cannot disregard their histories of disidentification with science and position themselves as always having excelled academically in science. Instead, they must find ways to improvise and reinterpret their past experiences in ways that allow them to position themselves in the present as moving towards science. Such identity work may occur as they engage in narrating, that is, making sense of past experiences by writing, speaking and thinking about them. By shaping the self-authoring that latecomers do as they make sense of their experiences in science, cultural models can also guide future participation in science and thus have longer term implications for latecomers' identification with, and persistence in, science. For example, a cultural model of latecomers as needing extra help in their first year was made available in the figured world of the science program through resources such as the requirement that latecomers (and only latecomers) must take a study skills course in their first year. While some latecomers rejected this cultural model in their narratives, others drew on it to make sense of their past failures and/or author themselves as able to succeed in the future, provided that they sought the extra help they needed. Using this latter self-understanding to guide their participation in the science program, some of these latecomers made an effort to access and use a variety of study resources (e.g., study guides and textbooks on learning techniques), which not only likely helped them academically, but had the potential to garner them positive recognition from meaningful others such as their teachers (Jackson, 2013).

Although the lens of identity is commonly used when studying issues of marginalization in science education, the concept of figured worlds is less commonly applied, particularly in postsecondary science studies, where, there are only two notable uses of figured worlds. Tan and Barton (2008b, 2010) conceptualized classrooms as multiple figured worlds and explored how they were shaped by teachers and students in ways that can offer a range of possibilities for students to author their identities. Tonso's analysis (2006) represented a campus engineering community as a figured world and documented powerful cultural forms of scientist and engineer that permeated that world. Although not focused on science, Hungerford-Kresser and Vetter's (2012) use of figured worlds has similarities to this study. They described the identity negotiations of a Latino student at university, showing how, in the figured world of the university, discourses acted as powerful constraints to their participant's ability to successful position himself within the figured world.

The figured world of the science program. Figured worlds exist at many different scales, often in a nested or overlapping arrangement, and therefore sharing many resources (Lemke, 2000; Reveles et al., 2004). As part of the larger research project in which this current study is based, Jackson and Seiler (2013) showed how the dominant cultural models of the Island College science program are connected with wider figured worlds, such as those of the Québec education system and the figured world of science. These cultural models figure a good science student as someone who earned good grades and followed a specific sequence of courses through high school and postsecondary education referred to as the *paradigmatic* trail. Such figurings tended to constrain latecomers' ability to identify with science, as they didn't fit these models of a good science student. Similarly, Jackson (2013) showed how, although each science classroom in Island College can be considered a unique figured world, the cultural models of learning they reproduced contributed to the overarching figured world of the science program. These cultural models, in which learning science was framed as a teacher-centred, sink-or-swim process, again tended to constrain latecomers' ability to identify with science, offering only passive forms of participation that didn't afford their active participation in learning science.

Fortunately, latecomers are not strictly limited to the cultural models made readily available in the figured world of the science program. Instead, despite the highly reproductive nature of figured worlds, there is also the possibility of resources being used in ways that can liberate participants from the constraints. Holland et al. (1998) explained, "The constraints are overpowering, yet not hermetically sealed" (p.18). Studying such moments of liberation allows us to understand not only how figured worlds can impede latecomers' persistence, but how latecomers may resist the constraining structures of privilege and influence that populate the figured world of school science. Such liberation is often referred to as agency on the part of the individuals' working towards liberation from the reproductive tendency of social structures, whether such identity work is conscious or not (Holland et al., 1998; Sewell, 1992). Agency can occur when an individual acquires new resources, uses the resources afforded by a figured world in novel ways, or draws upon resources from other figured worlds. It can also occur through the production of new resources which can afford new ways of participating in activities organized by the figured world, both currently and in the *future*. As an example of this latter type of production, Holland et al. (1998) showed how a group of Nepali women used a socially approved song genre to co-construct songs that resituated their subject positions as sad and unfair, which in turn, was used to organize opposition to some of the injustices these women faced in their day to day lives. However, even in such powerful cases of the production of resources for future identification with science, individuals cannot completely rid themselves of the constraints of the figured world in which they are participating. Instead, they work largely within the constraints to improvise new ways to position themselves within that figured world.

Solidarity

Research has shown that solidarity between members of a minority is an important way for students to integrate "into the college social and academic systems and thereby maximize the students' survival in college" (Nagasawa & Wong, 1999, p. 76). In this paper, solidarity is understood to be emotional "connections to specific individuals and to general collectives" (Elmesky & Seiler, 2007, p. 77) in the context of science. Solidarity is constructed when people recognize each other's shared knowledge of emotionally charged symbols and build further shared knowledge upon that. The positive emotional energy generated from the formation of solidarity makes it more likely that the people involved will use this shared knowledge as a resource in future science-related interactions. In this way, the formation of solidarity can have longer term implications for latecomers' identification with science and their persistence.

As demonstrated by Elmesky and Seiler (2007), the sharing of such emotionally charged knowledge and the accompanying construction of solidarity is constrained or afforded by the figured world in which participants are interacting. For example, in a traditional lecture, which is the common structure of classes in the figured world of the Island College science program (Jackson, 2013), there are few resources supporting any type of peer interaction and thus little opportunity for solidarity building interactions. In contrast, in the online forums that provide the data for this current paper, latecomers were prompted to discuss their experiences in science, good or bad, with each other. This provided them with multiple opportunities to share emotionally charged symbols (stories of good or bad experiences in science) in a science-related context, thus affording the construction of solidarity. This process will be explored in the analysis, along with other resources that latecomers constructed to support their identification with science.

Context

The four latecomer participants in this study, Shelley (age 18), Ben (age 17), Ingrid (age 19), and Kayla (age 17), were members of an Island College make-up physics course that I taught in the Fall semester of 2009. At that time, most Québec students took the same math and science courses until Grade 10. In Grade 10, students were streamed into either the advanced stream, often called the *science* stream, or the regular stream, often called the *lower* stream or the *social science* stream, although some schools also offered intermediate courses. In Grade 11, two science courses were offered: physics and chemistry. If students were not in the advanced stream, they were not usually permitted to take either Grade 11 science course. In Québec, secondary schooling ends at grade 11, after which students can enter the labor market or attend a Collège d'enseignement général et professionnel (CEGEP) such as Island College. CEGEPs offer two-year pre-university programs, three-year career programs, and shorter technical programs. The two-year pre-university science program is roughly equivalent to 12th grade and first year university elsewhere in North America. In order to access the pre-university science program at Island College, applicants are required to have graduated high school with grades equal to or greater than 70% in both Grade 11 science courses. If students are missing prerequisites upon graduation from high school, they may be permitted access to the CEGEP *preparatory science program*, at which point they then have two semesters to complete make-up courses.[28] If successful they will be accepted into the *pre-university science program*. Those trying to access university science in this way were termed latecomers to science by Jackson and Seiler (2013). In this paper, I extend this definition to also include similar students who are pursuing science-related career programs that require at least Grade 11 science, such as engineering technology, dental hygiene, and nursing. The four participants in the online thread analyzed in this paper are Shelley and Ingrid, who were trying to access the pre-university program, and Ben and Kayla, who were (at least initially) trying to access career programs. The following subsection gives a brief overview of each participant's history in science.

Participants: Shelley, Ben, Ingrid, and Kayla

After a successful year in Grade 9 biology and math, Shelley was placed in advanced Grade 10 science and intermediate math. However, she earned low grades in her first term and switched into the regular stream courses. She was therefore not permitted to take either physics or chemistry in Grade 11. In college, Shelley (re)took Grade 10 advanced science and math in order to access the Environmental Wildlife Management career program at City College, another CEGEP. She earned percentages in the 90s in both make-up courses and decided to pursue pre-university science instead. She enrolled in the preparatory science program where she took the make-up Grade 11 chemistry, physics, and advanced math courses. She failed physics and math and was therefore denied access to the science program. Instead of giving up, Shelley enrolled in

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[28] For reasons of brevity, this summary of the process of gaining access to the science program is overly simple (e.g., it omits discussion of bridging courses for those who earned below the 70% cut-off). However, it is sufficient for the purposes of understanding the latecomer participants' interactions discussed in this paper.

the preparatory program at a new college, Island College, enrolling again in the make-up physics (the course described in this paper) and math courses. In her first semester, when the online forum analyzed in this paper occurred, Shelley was experiencing difficulty increasingly identifying with science, but was successfully resisting being pushed out of science. She was thus stuck on the margins of science, or what Jackson and Seiler (2013) termed, a peripheral science identity trajectory. More details of Shelley's trajectory can be found in Jackson and Seiler's paper (2013) on latecomers' science identity trajectories.

In Grade 10, Ben was placed in intermediate math and advanced science, where his grades remained low but passing. His lack of advanced math prevented him from accessing physics in Grade 11 and thus in order to be accepted into his career program of choice, Engineering Technology, he needed to take make-up physics and math at CEGEP. Around the time of this forum, Ben decided to apply for pre-university science instead of the career program. At this point, Ben was located on an inbound science identity trajectory, meaning he was increasingly identifying with science (Jackson & Seiler, 2013).

Unlike the others, Ingrid was placed in the advanced stream throughout high school. Early in high school she was diagnosed with an auditory processing disorder, a learning disability that made it difficult for her to focus in classes such as science, where a lot of listening was required. She wanted to study fine arts in college and therefore didn't take science in Grade 11, although she did take advanced math. After completing her fine arts program at City College, Ingrid enrolled in the preparatory science program at Island College, hoping to find a way to combine arts and science in her future. At the time of the forum, Ingrid was also located on an inbound science identity trajectory.

Kayla was placed in the regular stream in Grade 10. In Grade 11 she took the advanced Grade 10 courses simultaneously with Grade 11 chemistry and physics (a load not usually allowed by Québec school boards). She passed the Grade 10 courses, passed chemistry with a low grade, but dropped physics after a few weeks. After graduation she enrolled in the business program at Island College, but switched out after only a few days and decided to pursue the dental hygiene career program instead. To access Dental Hygiene, a science-related career, she had to take the make-up physics course. At the time of the forum, Kayla was located on a peripheral science identity trajectory.

Methodology

This paper is part of a larger research project that strove to better understand how to support latecomers' persistence in postsecondary science. The first semester of this larger study incorporated an action research phase, in which I, as teacher and researcher, worked to better understand the challenges my latecomer students faced, not only for research purposes, but also to inform my teaching throughout the semester in order to better support their learning. The forms of data collection, such as the online forum explored in this paper, were designed with the purpose of giving students the chance to talk to both myself and each other about their experiences in science, with the hopes that by learning about their past experiences, I might better understand their current challenges. Also, in keeping with the action research methodology, it was hoped that reflecting on and sharing some of their past science experiences in the online forums, would support their persistence in the science program.

As data analysis ensued, it became apparent that, not only did the latecomers reflect on and share their experiences in science in the online forum, they often *did* reinterpret their past experiences in ways that better positioned them as legitimate science students. This led me to pursue the current line of study, exploring how latecomers with histories of being recognized as not smart enough to do science, demonstrated agency in identifying with science in an online forum. I do this by applying Gee's (2011a) method of critical discourse analysis (CDA) to one thread selected as a unique case (Yin, 2009) from a set of 178 drawn from the five online forums that took place over the first semester of the larger research project (August-December 2009). Although in many of the 178 threads, latecomers reinterpreted past experiences to envision a successful future in science, in a few threads, the latecomers were very active in such reconstructions. In particular, the selected thread emerged as an outstanding example of how an online forum conversation can result in the co-production of resources with potential to afford future identity work.

The Online Forum

The online forums were included in this course due to the demonstrated potential of online interactions to offer a *third space* (Bhabha, 1994) by increasing the "possibility for a negotiated re-imagining of cultural identity" (Bretag, 2006, p. 982). Here, I use the term *third space* to refer to spaces that bring multiple figured worlds together, thus creating more opportunities for participants to import resources from figured worlds other than school science and/or (co-) produce new resources to help them identify with science. This is in contrast to in-class interactions where the inherent traditionalism of the space imposes constraints on students' participation (Jackson, 2013). In the spirit of action research, this intent was explicitly expressed to participants in my introductory post on the forum:

> By allowing you to explore your prior experiences with science and to consider how they have influenced your current relationship with science, I hope that you may find new

ways to think about science, ways that allow you to succeed in your future (both in school and out).

The four participants, along with the other 36 class members, were required to contribute to five online forums worth a total of 5% of their final grade, 1% for each forum. In each forum, students posted original responses to a prompt provided by me, their teacher and researcher. For example, the first forum asked students, “What does science mean to you, and how do you see yourself participating in science (both now and in the future)?” Within the 2-4 weeks allotted for each forum, students were required to compose one original post and respond to two of their peers’ original postings (four in the third forum). Full marks were assigned as long as these requirements were met; no marks were awarded for length or quality. The average word length of original posts in all five forums was 141 words. Although every student did not always participate in every forum, particularly towards the end of the semester when exams were approaching, the average number of responses to peers was above the required number in the majority of forums. This indicated that students were engaged for reasons other than earning marks, as does the average number of views of each post (see Table 1). For the first forum, I wrote the first post to the topic question in order to encourage students’ participation. For the remainder of the forums, my posts consisted only of a re-statement and elaboration on the forum topic, as well as responses to students’ posts if no peers responded, so that all original posts received at least one response.

The thread selected for analysis was part of Forum #3 in which participants were asked to “reflect on how you have experienced science IN school. Have these experiences helped shaped what science means to you (or not)? Have they made you more or less interested in pursuing a future in science?” To elaborate I posted the following:

> Hello, I wasn't going to post anything this time, but I thought it might help you all overcome your fear of posting first, if I wrote something. In this forum, I would like you to reflect on some of your experiences with science in school. Anything that stands out to you... you could describe specific experiences, or just what it was like in general. These experiences may bring up good or bad feelings (or both or neither). I'd also like you to reflect on how these experiences affected your choices about taking science in high school, and about taking science now, in college. Enjoy, respond to each other and get the conversations going. Phoebe

As shown in Table 1, Forum #3 was allotted two extra weeks, with the added requirement that students respond to two additional peer postings. This decision was made in consultation with the entire class because many conversations still seemed in progress near the end of the regular two-week period.

Critical Discourse Analysis

Its view of identity as a process rather than a stable structure and its ability to connect identification processes across scales, from the micro of grammar up through the macro of figured worlds, makes critical discourse analysis an ideal method of analysis for exploring latecomers' identification with science in an online forum. CDA is a textual analysis that views language-in-use as always being political (Fairclough, 1995; Gee, 2004). It differentiates itself from standard discourse analysis because it is not "isolated from analysis of institutional and discoursal practices within which texts are embedded" (Fairclough, 1995, p. 9).

> Critical discourse analysis tends to begin from a poststructuralist skepticism toward the assumption that people have singular, essential social identities or fixed cultural, social class, or gendered characteristics. It assumes that subjectivities are strategically constructed and contested through textual practices and that they are crafted in the dynamics of everyday life. (Luke, 1995, p. 14)

Computer mediated communication. A text, in the sense of the unit of analysis of CDA, can refer to a variety of communication. In the present study, the text is computer mediated communication (CMC). The CMC aspect of the data makes discourse analysis particularly appropriate. In face to face (F2F) communication, body language and other visual cues play a large role in the construction of identity, but are difficult to capture and analyze. However in CMC, all cues are integrated into the text (e.g., emoticons, punctuation, capitalization, and abbreviations). The singular medium of CMC creates an environment in which the significance of each word and symbol is heightened, and thus lends itself well to discourse analysis (Benwell & Stokoe, 2006; Lamerichs & te Molder, 2003).[29]

Gee's CDA toolkit. Gee's method of CDA (Gee, 2011a, 2011b) is well suited to this study because it provides tools to explicitly explore identity construction in relation to figured worlds, therefore facilitating an exploration into how latecomers identify with science in an online forum. To carry out Gee's CDA, the online forum was transcribed into lines and stanzas, where each line contained a single clause, identified either by punctuation or a subordinating or

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[29] This study examines the construction of identity that occurs among latecomers in an online forum. Here, online identity, also referred to as virtual identity, is considered as real as identity constructed through F2F communication. Identity in any context is virtually and continually produced, thus virtual identity is merely "a prosaic term for identity work that happens online" (Benwell & Stokoe, 2006, p. 245).

coordinating conjunction (Gee, 2011b). Each line was labelled as shown in Table 2, where lines of the same number but different letters belonged to the same sentence. Blocks of lines were divided into stanzas, identified in the original text by a new paragraph. In the transcription, each stanza was separated from other stanzas by blank lines, as shown in Table 2.

Once transcribed, each line was analyzed using all 27 CDA tools Gee provides. Each tool asked a specific question of the data, forcing the analyst to pay attention to the minutiae of the language in use while simultaneously tying these details to what the participants "mean, intend, and seek to do and accomplish in the world by the way in which they have used language" (Gee, 2011a, p. x). For example, the Deixis Tool asked how the author used deictics (e.g., pronouns) and definite articles (e.g., *the* vs. *a*) to link what was written to a larger context and to make assumptions about what other participants already knew; the Social Languages Tool asked how the words and grammatical structures were being used to signal and enact a given social language; and the Politics Building Tool asked how words and grammatical devices were used to construct solidarity (among other social goods) and to distribute it to or withhold it from others.[30]

The tools were used in order of scale, where micro-scale tools such as the Deixis Tool were applied before larger scale tools such as the Social Languages Tool, which in turn was used before the Politics Building Tool. In this way, the findings of the smaller scale, lexico-grammatical tools, helped inform the analysis using the larger scale tools. For example, in the Deixis Tool analysis, it was noted that definite articles were used mostly in reference to courses/programs, for example when Ingrid called the science program, "*the* program," and Shelley referred to her high school stream as "*the* lower classes." Such a use of deictics assumed

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[30] A description of all 27 tools is given in How to do Discourse Analysis: A toolkit (Gee, 2011a, pp. 195-201)

that the other latecomers were familiar with the inner workings of the Québec Education system. When applying the Social Languages Tool, it was observed that the language of the Québec Education system was emphasized throughout the thread, in part through deixis as previously mentioned. In turn, when applying the more macro Politics Building Tool, findings from these previous two tools contributed to the understanding that the participants used the language of the Québec Education system to recognize each other as sharing similar experiences, thus supporting their co-construction of solidarity.

Although all 27 tools were applied to each line of the transcript, as anticipated, some tools yielded more illuminating information than others (Gee, 2011a). Three tools emerged as particularly relevant in understanding how the forum was used by latecomers to co-construct new resources to aid in their positioning of self and each other in the figured world of the science program: (a) the Politics Building Tool, previously described; (b) the Identities Building Tool, which asked, how did the participant's language position self and others and what kinds of subject positions did the participant recognize for others in relation to his or her own? and (c) the Figured Worlds Tool, which asked, what must be assumed about how the participant figured aspects of science to make deep sense of what he or she wrote? What subject positions, cultural models, practices, interactions, languages, people, objects, environments, institutions, and values make up these figured worlds of science, or in the terminology of this study's theoretical framework, what *resources* do participants produce or reproduce to position themselves in the figured world of school science?[31] As explained, these macro-level tools were applied last,

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[31] The wordings of these latter two tools have been modified to cohere with the terminology used in our theoretical framework, but their intent is the same.

allowing the preceding analysis to build a foundation for the insights gained into how the four latecomers used resources to identify with science in the online form.

Solidarity. While much of the construction of identity can be analyzed through CDA in ways similar to F2F communication, solidarity forming features are noticeably different due to the absence of commonly relied on aural and visual cues, such as synchronized movement, intonation, eye contact, and head nodding. Instead, solidarity building interactions are evidenced in online communication through positive politeness strategies including claiming common ground; conveying cooperation through techniques such as being optimistic and including each other in activities through pronouns such as we and us; exaggerating interest and emotion; and sharing personal information including details on one's emotional or mental state including the use of emoticons (Bretag, 2006; Darics, 2010). Accordingly, when using the Politics Building Tool, I looked for instances of such positive politeness strategies in the data in order to gain insight into any construction of solidarity that was occurring.

Analysis

Summarizing the essential findings of the CDA of one online forum thread, I will show how four latecomers, struggling against histories of being recognized as not smart enough to do science, participated in an online interaction in ways that co-constructed two mutually supporting resources to help them position themselves as moving towards science: 1) a cultural model in which asking questions was directly related to succeeding in science, and 2) solidarity with the other participants. A full transcript of the thread under analysis is presented in Table 3. However, before showing how the participants agentically carved out a position for themselves in science, evidence is first provided to show that they were indeed working within cultural models that constrained their ability to identify with science.

The Constraints of the Elite Figured World of the Science Program

The use of CDA revealed that strong constraints to latecomers' identification with science pervaded the online thread. Two of Gee's (Gee, 2011a) tools were particularly useful in this regard. Gee's Situated Meaning Tool asks what specific meanings listeners have to attribute to words and phrases, while his Integration Tool asks how clauses are integrated to create certain assumptions, or in other words, to produce or reproduce cultural models. For example, two clauses connected through a coordinating conjunction, such as *and* or *but*, are considered not very tightly linked, such as Shelley's statement, "I learned many things in that course and I had a good teacher" (2ab). In this case, Shelley was only hinting that having a good teacher was related to her learning many things. In contrast, clauses are much more tightly linked when one clause is subordinated to the other through a subordinating conjunction such as *because* or *although*. In such cases, the information presented in the subordinate clause is so tightly connected to the main clause, that this connection is assumed to be understood by the readers and does not require more explanation. For example, in Shelley's statement, "sometimes I wish I paid more attention because I could have learned more" (2cd), the casual connection between the paying attention and learning more is taken for granted. In other words, Shelley reproduced a cultural model in which the more one pays attention in school, the more one learns. In this way, subordinated statements give insight into the cultural models underlying participants' narratives and positioning of self and others. Again, in lines 3ab, "But I never felt very good in science and math because I was in the lower classes," we can see that Shelley's subordinate phrasing, ("because I was in . . . ") as well as the situated meaning of her terminology ("the lower classes") reproduced the cultural model that students who do not follow the paradigmatic trail are not cut out for science (Jackson & Seiler, 2013). This cultural model was supported by her other choices of language such as, “I made it into Math/Science 436” (4a), and “go further . . . and go for the science program” (8ab), where both phrases only make sense if one assumes that science is more valued than other fields. Similarly, in lines 4bc, “but dropped it because I wasn't doing too good and I just felt really stupid beside the people in those classes,” we can see that Shelley’s subordinate phrasing reproduced a cultural model in which students who get low grades are not recognized as smart enough to do science.

The importance of being smart to figuring who can do science was also evident in the latecomers’ use of derogatory terminology such as “stupid” (4c), “retard” (11a), and “pretty A.D.D.” (13b) when discussing having difficulty and feeling bad in science. Further evidence for the constraints the elite figurings of science imposed on the four latecomers is woven through the following explanation of how the latecomers were able to work within these constraints to successfully position themselves as having a future in science.

Working Within the Constraints to Co-produce Resources to Identify with Science

Due to their positions as latecomers to science, the four participants did not have access to the resources provided by the dominant cultural models of the science program to position themselves as good students (e.g., good grades and the paradigmatic trail) (Jackson & Seiler, 2013). However, the analysis that follows shows that the online forum provided them the opportunity to co-construct new resources with which they could carve out a space in the science program for themselves, envisioning a future in which they could be more successful. In successive postings, participants constructed, validated and extended a new cultural model in which past science failures were blamed on an inability to ask questions (rather than a lack of intelligence) which in turn was attributed to a feeling of being alone in not understanding the science being taught. This *asking questions* cultural model allowed them to talk about their histories of disidentification without taking up the subject position of being not smart enough to do science, thus breaking the implicit bond between getting good grades and being smart enough to do science, creating space for them in the elite figured world of science.

In addition, as they used this model to reinterpret their histories, they shared personal and emotional stories, which contributed to the co-production of solidarity. Solidarity is associated with positive emotion, being both produced by it and adding to it. Such positive emotion is something that can be carried forward (Collins, 2004), thus providing another resource for identification and positioning oneself with respect to science (Seiler & Elmesky, 2007). The most explicit and strongest identification with science occurred when participants used their solidarity in conjunction with the asking questions model to position themselves as capable of succeeding in science. In this way, the resources of solidarity and the asking questions cultural model were mutually supportive in affording latecomers' authorings of a successful future in science, which in turn had the potential to guide their future participation in science in ways that could better support their academic success and their persistence (e.g., by asking questions in class).

A heuristic of the asking questions cultural model is given in Figure 1, where solidarity is included to show how participants used it with the cultural model to author a more successful future in science. As the term co-production implies, "such reframings are negotiated 'achievements' of participants" (Mishler, 1999, p. 85), rather than individual accomplishments, and hence the evidence that follows shows not only how the model and the accompanying solidarity was produced and used, but that the production was gradual as successive posts strengthened and extended the resources.

In the following analysis, in order to further familiarize the reader with how Gee's toolkit was applied to the data, at times, the name of a particular tool that largely supports the interpretation being made is included in parentheses, with a short explanation where needed. However, this provides only a small sampling of the ways in which the 27 tools were used to draw the interpretations presented here. As discussed in the Methodology, each finding was the work of many inter-related tools and thus it is not possible to show every tool that contributed to each finding. Also, because the Identities Building Tool, Figured Worlds Tool, and Politics Building Tool permeate the entire analysis, they are not shown as supporting any one particular claim. Rather, the reader should assume that these three tools have been applied throughout the entire analysis.

Shelley: Producing and using the asking question cultural model. As the author of the initial post, Shelley initiated the construction of the asking question cultural model, putting it forward for others to take up and extend. Exercising agency, Shelley began by reframing her negative experiences in high school science. Her production of the asking questions model was evident through her use of causal subordinate phrases, which increased noticeably when she wrote about the importance of asking questions. At the start of her post, where she didn't write about asking questions, Shelley mainly used loose forms of integration, relying largely on coordinating conjunctions to link clauses (e.g., 1bc; 2cd). However, when discussing the importance of asking questions, she subordinated several clauses through conjunctions such as *because* (e.g., "when I was in the lower classes I did pretty good [be]cause I tried and didn't feel scared of asking questions" 5ab). By doing this, she produced the assumption that doing well in science was not related to her level of intelligence, but instead with her level of comfort asking questions. In contrast, she authored her lack of success in the advanced courses ("when I made it into Math/Science 436" 4a) as being due to her inability to ask questions: "and I just felt really stupid beside the people in those classes and therefore couldn't ask questions. This causal model that Shelly began to construct connected whether or not one does well in science with the willingness or reluctance to ask questions, the latter of which was caused by feeling alone and "stupid." By splitting apart the normally implicit connection between grades and intelligence/ability to do science, Shelley began to counter the constraints of the figured world of the science program. In doing so, she also provided opportunities for others in the forum to take up the asking questions cultural model and apply it to their own situations, which if they did, would provide recognition of her authoring of herself as having a future in science. This would not only help her to successfully identify with science in that interaction, but also strengthen her resources for doing so in future instances.

Shelley's use of the asking questions model to resist being positioned as not smart enough to do science was further evident through her choice of feeling and doing verbs when referring to issues of smartness and grades. Gee's Why This Way and Not That Way Tool asks why the author designed the sentence in the way they did and not some other way. Rather than authoring herself as someone who never <u>was</u> very good in science and math, Shelley authored herself as someone who "never <u>felt</u> very good in science and math" (3a). Instead of representing herself as not <u>being</u> good at science, she represented herself as not "<u>doing</u> too good" in science (4b), where the alternative verb choices would have positioned her as someone who wasn't smart enough to do science. Instead, her verb choices created the perspective that her troubles with science were due to the context and her behavior in that context (e.g., not feeling able to ask questions) rather than a lack of intelligence, helping her author herself as capable of succeeding in science despite the constraints of the good grades model and the elite science cultural model.

Shelley's initial post signaled a desire for solidarity with other latecomers, evidenced by the sharing of her private, emotional history of disidentification with science (e.g., "I never felt very good in science and math" 3a, "I just felt really stupid beside the people in those classes" 4c). Sharing of personal and emotional information has been shown to indicate movement towards solidarity because of the trust implied in such sharing (Bretag, 2006). Shelley's trust in others and accompanying plea for solidarity was augmented by the signing of her name, which gave her post an even more personal touch (10). Name signing was unnecessary because the poster's name was automatically inserted at the top of their post, and it occurred very rarely in these forums. This suggests that the online forum provided Shelley with a way to seek and gain solidarity from her peers.

Ben: Affirming the model and building solidarity. In his response, Ben took up and applied Shelley's asking questions model to construct to his own story of being recognized as not smart enough to do science. First, Ben mirrored Shelley's careful lexicogrammatical positioning, telling her, "Don't worry about <u>feeling</u> like a retard" (11a), thus resisting positioning her and himself as not being smart enough to do science, although acknowledging that they were once recognized as such. Gee's Cohesion Tool asks how cohesive devices, such as similar words, are used to connect pieces of text. By opening with the term "retard," Ben referred back to Shelley's discussion of feeling "stupid" in high school science, showing that that part of Shelley's post, which was the genesis of the asking questions model, was going to be the theme of his post. According to Gee's Topics and Themes Tool, the theme provides a framework for the interpretation of what follows; thus, by connecting his theme to Shelley's discussion of asking questions and feeling stupid, Ben made this developing cultural model the theme of his post. Although Shelley began its production, the asking questions model only took up six of 22 lines of her initial post. In contrast, Ben's post was mostly focused on this model (five of six lines), evidencing its ongoing co-production. Simultaneously, by demonstrating his empathy to her situation, Ben's opening phrase also served to build solidarity with Shelley (Bretag, 2006).

Next, Ben shared his own history of being recognized as not smart enough to do science, sharing personal and emotional information and also claiming common ground with Shelley, both indicators of building solidarity (Bretag, 2006). However, although he applied the asking questions cultural model to his own narrative, he did so more loosely than Shelley, suggesting that he did not yet fully subscribe to the model. Gee's Connections Building Tool asks how words and grammar are being used to connect or disconnect things or ignore connections. In lines 11bc, "I had like a 65 average throughout my whole math and science career in high school, I did not ever want to ask anything because I was probably one of the only people lost," Ben connected his low science grades with a reluctance to ask questions, which in turn he linked to feeling alone and being lost (this latter being an extension of the asking questions model). However, he did so by using only a comma rather than an integrating conjunction or adverb, thus not fully avoiding the interpretation that his low grades were due to academic inability. Similarly, although he used a feeling verb to not position Shelley as not smart enough to do science, he used identifying verbs (Halliday & Matthiessen, 2004) to author himself as not able to do science (e.g., "I <u>had</u> like a 65 average" 11b, "I <u>was</u> probably one of the only people lost" 11c). Thus, despite applying and extended the asking questions model, Ben's reluctance to fully it take up, further evidences the power of the dominant cultural models to figure those who don't get good grades as not being smart enough to do science.

Ben’s final sentence, “Haha good to know I am not alone” (12), followed directly after he stated that he didn’t want to ask questions because he was probably one of the only confused students (11c). Gee’s Topic Chaining Tool asks how the topics of all main clauses are linked to create an overall topic or coherent sense of being about something for a stretch of writing. This helps us see that, not only did this sentence of Ben’s further build solidarity, it hinted that, he, and by association also Shelley, may be more inclined to ask questions in class now that they know they are not alone. This link between the solidarity produced and the use of the asking cultural model to identify with science will be further explored as the interdependence of these two resources unfolds.

Ingrid: Extending the model and building solidarity. Ingrid’s post, which followed Ben’s, was entirely devoted to the asking questions cultural model, whose increasing centrality to successive posts evidenced its continued co-production. In her post, Ingrid extended the model, rephrasing the practice of asking questions to speaking up, “I was really insecure about it for most of highschool, which means I never really spoke up when I got lost” (13cd). Here, Ingrid’s rephrasing had more assertive connotations, where instead of just asking for help, one was taking charge of one’s learning.

Like Ben, Ingrid’s claiming of common ground (e.g., “I can totally relate” 13a) and her sharing of personal and emotional information (her history of insecurity and fear of asking questions in science) continued to build solidarity among the participants, who were now a collective of three. Ingrid extended the model by suggesting that asking questions is not just a possibility now that they know they’re not alone, but a responsibility, “Now I realize it's helpful to say something because other people get lost too, often they're just too shy to do anything about it” (14ab). Gee’s Subject Tool asks why speakers have chosen the subjects/topics that they have and what they are saying about these subjects. Here Ingrid's used the third person in in this sentence (i.e., "other people," "they're"), which contrasted with her use of "you" to refer to Shelley and possibly Ben in her next sentence. This created the perception that she wasn't including Ben and Shelley in that group of people too shy to speak up, intimating that they were in the collective of people who now understood that they were not alone and thus were no longer afraid to ask questions. In this way she used their increasing solidarity in combination with the asking questions model to position the three of them as being able to succeed in science in the future.

In her final sentence, Ingrid again positioned Shelley and possibly Ben (and therefore herself as part of the collective), (and therefore herself as part of the collective), as capable of succeeding in science, writing, "It's really great that you didn't let it discourage you and that you're giving the program a chance" (15ab). Here, like them, she blamed the educational context (not feeling able to ask questions) for their negative experiences, complimenting them on not letting these experiences discourage them and for giving the science program <u>a chance</u>. This is in contrast to alternative phrasing (e.g., giving the program <u>a try</u>) which would have placed the blame for negative experiences on them rather than the program. Ingrid's positive theme "It's really great that," complimented Shelley and possibly Ben, thus continuing to build solidarity (Bretag, 2006) and recognizing them as capable of succeeding in science.

Kayla: Building solidarity but not the model. Kayla also shared details of her history of not being recognized as smart enough to do science in high school, thus claiming common ground with the other three latecomers to science. Opening with, "i am soo happy that there are people that sometimes have no idea of whats going on, I was sure I was alone. I was the same in high school" (16-17a), Kayla further strengthened the growing solidarity with her use of exaggerated excitement and very informal language and punctuation, which are common solidarity building techniques (Bretag, 2006). However, in contrast to the other posters, Kayla didn't use the asking questions cultural model to resist being positioned as not smart enough to do science. Instead, she authored herself as not being good at science, stating that she "wasn't the greatest" at math and science, emphasizing the associated negative emotion with a sad face ":(" (17b), again highlighting the constraints of the dominant cultural models of the figured world of the science program to latecomers' ability to identify with science.

Shelley: Putting it all together. In her final post, Shelley used the achieved solidarity in combination with the asking questions cultural model to make explicit a way to succeed in science in the future: keep asking questions. This resource positioned all four latecomers in a new way that countered the dominant cultural models of the figured world of the science program which tended position them as not being smart enough to do science. In this way they were able to negotiate a place for themselves in the figured world of the science program, thus identifying with science in that particular interaction.

Unlike her first post, Shelley's last post was built entirely around the asking questions cultural model, serving to consolidate, or solidify, the co-produced model that she initiated in her original post. She also continued to build solidarity, demonstrated by her use of exaggeration, optimism, laughter, informal language, emoticons, as well as, of course, her explicit statement that she was not alone "Wow!! Good to know I am not alone :)" (18-19a) (Bretag, 2006). Shelley then drew on this solidarity to reify the asking questions cultural model in the form of a prescription for success that they could all draw on in the future, writing, "lets keep asking questions then lol" (19b). Here, for the first time, the collective was given status as a viable entity through the use of the collective pronoun *us,* ("lets") (Bretag, 2006), demonstrating the important role solidarity played in participants' effective use of the asking questions cultural model to identify with science in this interaction. Also, in being reified as a prescription for success, the solidarity and asking questions model took on a more portable form, which could potentially be used in future interactions to help them identify with science—not only by helping them continue to make sense of their histories of disidentification with science, but also by helping them participate in ways that could lead to more academic success, that is, by actually asking more questions.

More evidence of the co-construction of solidarity. Gee's Social Languages Tool enables us to further understand the generation of solidarity among the participants. Throughout the online conversation, participants used three styles of writing to bid for recognition and to recognize each other in ways that built solidarity. Participants bid for recognition as teenagers by writing the majority of their posts in an informal day-to-day language exemplified by words and phrases such as "totally relate" (13a), and "I had like" (11b). Participants also bid for recognition as online users, permeating their posts with an online language exemplified by informal grammar such as the use of run-on sentences, absent capitalization ("i,"), creative punctuation ("Wow!!"), typing errors, purposeful or otherwise, ("whats," "soo"), and acronyms and emoticons ("lol," ":(," ":)," and "haha"). A third style important to the process of identification in this thread was the language of the Québec education system. This was brought into the thread through instances of specific terminology, such as "I made it into Math/Science 436," "65 average," "the program," and "I had to do math 436, and chem." By making these references, participants made assumptions about shared understandings of these terms and in doing so they recognized each other as students of the Québec science education system. In this way, by using these three social languages, participants further claimed common ground with each other, strengthening their solidarity.

Gee's Relationships Building Tool asks how words and grammar are being used to build and sustain or change relationships. This tool helped highlight another pattern that persisted throughout the online forum: although the overall emotion associated with their shared histories was negative, the emotion produced through sharing these stories was positive. This was evident in the contrast between the negative affective language incorporated in their stories, such as "stupid," "scared," "retard," and "insecure," and the positive affective language they used in responses to each other's stories such as "It's really great," "I am soo happy," "Wow!!" ":)", "lol", and so forth. Similarly, each participant reaffirmed the importance of the collective by making reference to their sameness in a positive manner: "Haha good to know I am not alone," "I can totally relate," "i am soo happy," "Wow!! Good to know I am not alone :)." This positive language, further verified the successful construction of solidarity (Collins, 2004; Seiler & Elmesky, 2007)

Discussion

The analysis showed that, even within the constraints of the elite figured world of the science program, given the opportunity to interact with each other in an online setting, latecomers to science *can* produce resources that help them make sense of their histories of disidentification in ways that position them as capable of succeeding in science. The four participants in this study were able to co-produce two new resources that allowed them to author successful futures in science despite their histories of academic difficulty. Together, these resources, solidarity and the asking questions cultural model, broke apart the normally unchallenged bond between good grades and being smart, creating a space for the latecomers within the elite figured world of the science program.

Implications for Theory and Practice

Participants' use of the asking questions cultural model to reframe their histories of disidentification created a small but important space in the figured world of the science program by separating the closely linked concepts of grades and intelligence/ability to do science; however, it didn't inherently position the latecomers as capable of succeeding in science. Similarly, the production of solidarity meant the four latecomers identified with each other, as well as the acknowledged "others" who also sometimes felt lost in science class. Importantly, when the latecomers used their constructed solidarity in tandem with the asking questions model, they were able to position themselves within the space they created in the figured world of the science program, that is, as capable of succeeding in science in the present/future despite their history of academic difficulty. This strengthened their identification with science within their interaction, and even reified the combined solidarity and asking question model into a prescription for success in science that they could potentially use to guide their future participation (e.g., asking questions in future science classes). The interdependence of the production of both resources and their strength when combined highlights the complexity of identity negotiations and suggests that the more resources made available to latecomers (and opportunities for producing or co-producing new resources), the more likely they are to be successful at identifying with science.

Although given a different set of latecomers, a different cultural model might have been produced, the asking questions cultural model does provide direction for teachers wishing to better support latecomers to science. The importance of being able to ask questions in class to latecomers' identification with science also arose in the larger research project in which the current student is based. Unlike the traditional science student, latecomers come into the postsecondary classroom with histories of being recognized as not smart enough to do science, and thus, without support, they are less likely to risk similar negative recognition by asking questions in class (Jackson, 2013; Jackson & Seiler, 2013). To better support such students, teachers could strive to achieve a classroom atmosphere in which asking questions is explicitly encouraged and trust and respect amongst peers (and teacher) are fostered. The value of such an interactive environment to all students is well supported in the literature, and regardless of whether or not all latecomers struggle with the same issues as the participants in this study, such an effort would have positive educational outcomes (Teixeira-Dias et al., 2005). However, the larger research project in which the current study is based, found that such an environment is not the norm in the Island College science program (Jackson, 2013).

This above recommendation is further supported by the fact that, in the make-up physics course, Shelley, Ingrid, and Kayla often asked questions in class, and Ben did less frequently, although he experienced less difficulty academically than the other three and thus seemed to have fewer questions. Early on in this class, as students' past histories of negative recognition and their inhibitions around garnering further such recognition emerged as part of the action research cycle, I made more of an effort to encourage them to speak up in class and took greater care to always respond to any contribution with positive recognition, such as "I'm really glad you asked," or "that's a good question." The importance of such an approach was acknowledged by Ingrid in an email she spontaneously sent to me at end of semester, "You never got frustrated if someone didn't understand and you were always willing to help. . . . The atmosphere in your classroom was really good because of this. "[32]

In Elmesky and Seiler's (2007) study, the shared knowledge (e.g., handshakes and dance moves) were associated with *positive* emotion in the participants' lives, contributing to the positive emotion generated during the formation of solidarity. In contrast, the four latecomers in the current study shared *negative* emotionally charged histories of being recognized as not smart enough to do science and being too scared to ask questions. However, as shown, the solidarity constructed as they shared their stories and built the asking questions cultural model still resulted in overall positive emotions, demonstrating that opportunities to discuss their struggles in science can provide latecomers' with potentially useful resources (e.g., solidarity) for identification with science. Also, paralleling Elmesky and Seiler's (2007) high school study, the latecomers produced resources and shared symbols that were largely foreign to the figured world of the science program, emphasizing the importance of providing opportunities for students to import resources from other figured worlds as well as to construct new resources.

As Collins (2004) explained, successful solidarity building interactions must continue to take place or the corresponding emotions of group membership and solidarity will fade. It is therefore not only important to provide latecomers with an opportunity to construct solidarity

[32] It was not observed whether or not there was an increase in the four participants' asking of questions in our make-up course following the mid-semester online thread analyzed in this paper. However, because the course was composed mostly of latecomers to science and because I made an explicit effort to encourage questions early on in the semester (before this particular forum took place), it seems likely that the participants did not need their new resources to guide their participation in this course.

and other resources to help them make sense of their histories of disidentification in new ways, but to provide *continuous* opportunities for such solidarity building around their struggles with science. This supports the findings of Barton (1998), who argued that, in order to help marginalized postsecondary students identify with science, it is important for teachers to prioritize conversations that allow students to talk about their struggles on an ongoing basis.

In particular, it is recommended that online forums be used to promote such productive conversations. Not only is the digital world an important communication medium in youth's lives today, but the analysis found that the online forum did indeed provide a third space in which multiple figured worlds came together to provide an ideal environment for co-production of new resources to afford identification with science. Other features of the online forum also lent themselves to the co-production process. For instance, in order for the process of co-production to begin, Shelley had to be brave enough to put her personal and emotional experiences and ideas out into the social sphere for others to take up or critique. Antaki, Ardévol, Núñez, and Vayreda (2005) showed how, in an online thread, the initial poster has more freedom to take such risks because he or she can assume the reader has positively navigated his or her way to the post through the subject line, and thus the initial poster is less vulnerable to criticism. In Shelley's case, the subject line, "Highschool vs. College," alerted readers that her post was going to focus on the differences between the two levels of schooling – and given that latecomers often had some difficulty in high school science, it is likely most readers would correctly assume that she was going to discuss her difficulties in high school. Also, the asynchronous format allowed each participant to offer more detailed and personal contributions to the conversation than would be possible in F2F communication (Clarke, 2009), thus allowing the asking questions cultural model to gain depth and sturdiness, eventually resulting in its reification as a prescription for future success.

Lastly, the importance of solidarity to the four latecomers' identity work around science in this forum suggests that any solidarity building strategies teachers can build into their classes would be beneficial for latecomers. Possibilities include collaborative activities, group work, friendly team competitions, hands-on construction projects, and small group discussions. Such activities contrast with the current teacher-centered practices that are the norm in the Island College science program (Jackson, 2013).

Conclusion

Supporting the findings of Jackson and Seiler (2013) and Jackson (2013), the online thread analyzed in this paper provided further evidence that latecomers' participation in their science classes is constrained by the elite figurings of science. Extending these findings, the micro-scale nature of this analysis provided insight into how, given the opportunity to interact and discuss their difficulties in science in an online forum, latecomers can agentically co-construct resources for making sense of their histories of disidentification in ways that allow them to author a space for themselves in the elite figured world of the science program. Such positionings and the related resources including solidarity can not only help latecomers make sense of their past experiences in science, but may also help latecomers to participate in science in ways that are more likely to lead to success and recognition (e.g., asking more questions in class). Consequently, the resources for identity work produced during such interactions may have longer term implications for latecomers' identification with, and persistence in, science.

This paper, and the larger project in which it is based, is the first research foray into understanding the challenges latecomers to science face and how they can be better supported.

Future research should continue to explore ways to make more resources available for latecomers' identification with science, including working closely with latecomers in the classroom to not only produce resources supportive of identification with science, as was done in this study, but to support the use of these resources over time, providing further insight into how such resources can play out in terms of persistence.

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Table 1: Summary of online forums.
Includes contributions from all 40 class members. Does not include contributions from teacher/researcher.

	Time Allotted	**Requirements**		**# of OPs**	**Avg. Responses/OP**	**Avg. # views/OP**	**Avg. # of words in OP**	**Min-Max # of words**
		Original posts (OP)	Responses					
# 1	2 weeks	1	2	39	2.0	23	139	32-436
# 2	2 weeks	1	2	39	1.9	18	132	46-244
# 3	4 weeks	1	4	37	4.1	27	120	49-277
# 4	2 weeks	1	2	34	2.6	19	160	62-298
# 5	2 weeks	1	2	29	2.3	15	160	94-396

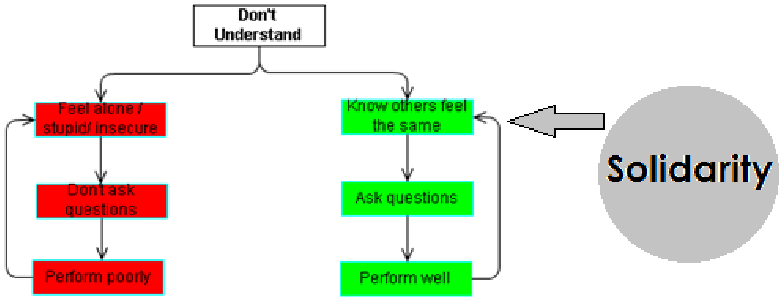
Table 2: Excerpt from transcript.
Sentence 15 is part of a larger stanza not shown here. Sentence 16 is a full stanza. The complete transcript is given in Table 3.

15a	Now I realize it's helpful to say something because other people get lost too,
15b	often they're just too shy to do anything about it.
16a	It's really great that you didn’t let it discourage you
16b	and that you're giving the program a chance.

Table 3: Complete transcript of thread from Forum #3.
This thread was initiated by Shelley in response to the prompt: Reflect on how you have experienced science IN school. Have these experiences helped shaped what science means to you (or not)? Have they made you more or less interested in pursuing a future in science?

Shelley	**Title: Highschool vs College**	
	1a	In Highschool,
	1b	I had to take biology in grade 9
	1c	and it was a fun course.
	2a	I learned many things in that course
	2b	and I had a good teacher,
	2c	sometimes I wish I paid more attention
	2d	because I could have learned more.
	3a	But I never felt very good in science and math
	3b	because I was in the lower classes.
	4a	Specially in grade 10 when I made it into Math/Science 436
	4b	but dropped it because I wasn't doing too good
	4c	and I just felt really stupid beside the people in those classes
	4d	and therefore couldn't ask questions.
	5a	Although when I was in the lower classes I did pretty good,
	5b	cause I tried and didn't feel scared of asking questions.
	6	I really never thought I would be going in the direction of science in college.
	7a	Intell Grade 11 when I had decided I wanted to go into a biology/chemistry carrer course in college,
	7b	and I needed pre-requisits(math/science436 and chemistry).
	8a	But doing those first pre-requisits math/science 436 I decided I would go further
	8b	and do Math 536 and physics and go for the science program instead.
	9	College is really more when I realised science was what I wanted to do.
	10	Shelley
Ben	11a	Don't worry about feeling like a retard,
	11b	I had like a 65 average throughout my whole math and science career in high school,
	11c	I did not ever want to ask anything because I was probably one of the only people lost.
	12	Haha good to know I am not alone
Ingrid	13a	I can totally relate,
	13b	I'm pretty A.D.D.
	13c	and I was really insecure about it for most of highschool,
	13d	which means I never really spoke up when I got lost.
	14a	Now I realize it's helpful to say something because other people get lost too,
	14b	often they're just too shy to do anything about it.
	15a	It's really great that you didn't let it discourage you
	15b	and that you're giving the program a chance.
Kayla	16a	i am soo happy that there are people that sometimes have no idea of whats going on,
	16b	i was sure i was alone.
	17a	i was the same in high school,
	17b	i had to do math 436, and chem but i wasn't the greatest at it :(.
Shelley	18	Wow!!
	19a	Good to know I am not alone :),
	19b	lets keep asking questions then lol

Figure 1: Heuristic of the asking questions cultural model and solidarity co-produced in online thread.



Chapter 5: Conclusion

Although it has been acknowledged that students who do not follow the traditional route through high school and directly into postsecondary science are less likely to persist, particularly when these students have a history of academic difficulty (American College Testing, 2006; Chen & Weko, 2009), little research has been conducted on the challenges that these students face when trying to succeed in postsecondary science (Mueller, 2008). Addressing this oversight, the present research program sought to gain an understanding of how the persistence of such students, termed *latecomers to science*, can be better supported. This was accomplished through a case study (Yin, 2009) of latecomers' identification with science in the Island College science program. From this overall case study, three manuscripts were produced, each of which took a qualitative approach to exploring latecomers' identification with science at different but overlapping scales of analysis, from the micro-scale of identity work occurring in interaction, to the self-authoring that occurred through narration, to the macro-scale of the figured world of the science program and the constraints and affordances this figured world exerted on latecomers' science identity trajectories. The following sections shows how the theoretical framework used in this research afforded a deeper understanding of persistence in latecomers and summarize the key insights obtained from the research. Following that, more specific implications for practice and directions for future research are discussed. Next, implications for practice are discussed, followed by directions for future research.

Summary of Findings and Original Contributions to Knowledge

An important contribution of this research is the theoretical framework itself, which drew from theories of social practice, particularly Holland et al.'s (1998) concept of figured worlds and an adaptation of Wenger's (1998) identity trajectories. In this framework, latecomers' identification with science was viewed as continually being under negotiation, afforded or constrained by the resources, including cultural models, available in the figured world of the science program in which the students were trying to successfully participate.

Due in large part to the forces exerted by this figured world, but with room for individual improvisations (or agency), over time, latecomers' identification with science formed general patterns, called trends. In the second chapter of this dissertation (*Science identity trajectories of latecomers to science in college*) these trends were analogized to a curve-of-best-fit on a scatter plot of an individual's identification with science vs. time. Similarly analogizing identification with science to motion towards science, these trends indicated acceleration towards (inbound) or away (outbound) from science, or neither, in which case the latecomer remained at the margins (peripheral) of science. In keeping with this physical analogy, acceleration was understood as resulting in their trajectories gaining or losing momentum, thus supporting or hindering their persistence. As demonstrated initially in Chapter 2 and subsequently in the other chapters, this physical analogy between identification and motion provides a language for talking about longitudinal processes such as persistence in relation to the often ill-defined concept of identity. In this way, it answers increasing calls for a theoretically and methodologically coherent use of identity in science education research (Jackson, Ardenghi, & Seiler, 2011; Johnson, 2012; Shanahan, 2009).

Further addressing these calls, the strength in the theoretical framework used throughout this dissertation does not lie solely in the physical analogy, but also in its integration of Holland et al.'s (1998) figured worlds into science identity theory, particularly science identity trajectories. Despite the potential of figured worlds for representing social structure without compromising the conceptual dynamism of identity construction, figured worlds remain little used in science education research. This dissertation provided a clear example of how figured worlds can be coherently used to understand how students' identification with science is shaped, in large part, by the dominant cultural models of the figured world, while still remaining open to individual agency. By theorizing cultural models as linked with other resources that are acquired by latecomers as they participate in activities organized by the relevant figured world, this framework provided a way to talk about identity as tending to form patterns over time. However, it did so while understanding identity as being eternally dynamic, rather than as something that is carried across time or context (rather, it is resources that are portable). This framework also borrowed from Sewell's (1992) understanding of resources as contributing to agency, rather than only constraining agency, when individuals use resources in new ways, import resources from other figured worlds, or construct new resources.[33]

At every level of analysis, and regardless of the data type to which it was applied, this framework highlighted the connections between the social forces at play and how they impacted individual latecomers and their teachers, while always leaving room to explore individual improvisation or agency. This allowed for an enhanced understanding of the different and interrelated ways that latecomers' identify with science (e.g., in interaction, through narration and sense making of experiences, and in trajectories over time). On their own, each of these understandings of latecomers' identification provided new and practical insights into how latecomers' persistence in science can be better supported. For example, by applying this framework to students' narrative data, Chapter 2 was able to show how the dominant cultural

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[33] Sewell actually theorized resources as separate but dialectically linked to schema, where schema are roughly comparable to the concept of cultural models, and thus are encompassed in the term *resources* used in this dissertation.

models of the science program played a large part in constraining latecomers' ability to construct inbound trajectories. In contrast, by applying this framework to classroom and lab observations, as well as to teacher interviews, Chapter 3 was able to show the importance of recognition to latecomers' science identity trajectories. Viewed together, the insights provided by this framework created a rich picture of the extent to which latecomers struggle under the heavy constraints imposed by the figured world of their science program, and also the overlapping figured worlds of science, science education, and even individual science courses.

Another important theoretical and methodological contribution made in this research was the emphasis on both students' authoring of self in relation to science and identity construction in interaction. Whereas others have applied Holland and Lave's (2001) notion of thickening of identities by looking at how identity sediments and traces become salient in future instances of identity work of students in science, Chapter 2 showed that this thickening is continuous, as participants do identity work in their thinking, writing, and talking about themselves in science. This, therefore, provided a new approach to the study of science identity trajectories, drawing on different types of data (narrative vs. interactional) as well as new conceptual structures (e.g., trends in science identity trajectories).

The findings of Chapter 2, which was aimed at gaining a broad picture of the latecomers in this study, supported the concerns for latecomers to science expressed, but not explored, in the literature, in that out of 18 latecomers, only eight persisted through their first year.[34,35] Looking into the forces behind such a poor persistence rate, the analysis showed that two dominant

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[34] Here, persistence means that the students completed the preparatory science program successfully and by the end of their first year at the latest, had accessed and remained enrolled in the pre-university science program.

[35] Only five persisted through to graduation from the pre-university science program.

cultural models of the Island College science program tended to exert a negative force on latecomers' trajectories, making it difficult for their trajectories to gain positive momentum, therefore hindering their persistence in science. These cultural models figured a good science student as someone who (a) consistently achieved good grades and (b) followed a traditional (paradigmatic) sequence of courses through high school, into and through college, and beyond. Although the latecomers did improvise with the available resources in order to author themselves as moving towards science, such improvisations tended to only be successful for the duration of the 18 month research period when the student's inbound identity trajectory was also afforded by the two dominant cultural models. Thus, latecomers to science would greatly benefit from an increase in the diversity of resources made available to them for authoring themselves as moving towards science, in ways that can counteract the dominant cultural models that tend to position them as non-legitimate science students. The implications this has for practice are discussed at length in the next section.

Building from the preceding chapter, Chapter 3 (*Identity work in the college science classroom: The cases of two successful latecomers to science*) looked further into the resources available in the figured world of the Island College science program that were more or less supportive of latecomers' persistence. In particular, it was investigated how identity constructions that occurred as students participated in their courses contributed to latecomers' science identity trajectories and thus their persistence in science. Exploring how this process was shaped by the available resources, including the overarching cultural models of learning that structured latecomers' science courses, the research presented in Chapter 3 followed two successfully persisting latecomers through their first year in the pre-university science program. Drawing on classroom and laboratory observations, as well as student journals, student interviews, and teacher interviews, it was found, that although it was possible for latecomers to engage in successful identity work in their science courses, the prevalence of the teacher-centred and sink-or-swim cultural models of learning greatly constrained their ability to do so, and sometimes resulted in them being positioned in the less powerful subject positions of a good student, rather than being good at doing, or interested in, science. Again, the implications this finding has for practice is discussed in the next section.

Although the importance of identity work in the science classroom for marginalized students has been clearly demonstrated in K-12 studies, it has been largely ignored in the higher education science education literature. By highlighting the significant impact that latecomers' identity work in their courses can have on their identity trajectories and thus their persistence in science, the research presented in Chapter 3 made an important contribution to the literature on persistence in postsecondary education.

Lastly, the research presented in Chapter 4 (*I am smart enough to study postsecondary science: A critical discourse analysis of latecomers' identity construction in an online forum*) focused on an aspect of latecomers' identification with science that emerged in the other two chapters: their ability to improvise with the available resources, that is to exercise agency, in order to free themselves from some of the constraints of the figured world of the science program (Holland et al., 1998). Drawing from the online forums conducted as part of the first semester of data collection, in this chapter, one thread was analyzed in which four latecomers co-constructed new resources to support their identification with science. Adding to the findings of the other two papers, Chapter 4 provided further evidence that latecomers' participation in their science classes is constrained by the elite figurings of science. Extending these findings, it was shown that the four latecomers co-produced a cultural model in which the ability or inability to ask questions led respectively to success (good grades) or failure (low grades) in science, while simultaneously forming solidarity with each other. Using this model to reinterpret their histories of being recognized as not smart enough to do science in conjunction with their newly formed solidarity, participants were able to not only successfully position themselves in the elite figured world of science, but to reify the result in a form that could potentially support future identification with science.

This third approach to exploring latecomers' identification with science contributed a deeper insight into how, given the opportunity, latecomers to science can (co-)construct their own resources for identifying with science. In particular, Chapter 4 presented evidence that the third space (Bhabha, 1994) provided by online forums affords identity work by bringing together multiple figured worlds rather than only valuing the figured world of the science program. This supports parallel findings in other research contexts (e.g., Bretag, 2006). Also, the research presented in Chapter 4 extended the body of work that has found solidarity to be a valuable resource for minorities' identification with, and persistence in, postsecondary education (e.g., Nagasawa & Wong, 1999) to the case of latecomers to science.

It is clear from the findings described, that despite going to extra lengths to access postsecondary science, the latecomer participants struggled to persist in the science program. Before now, latecomers to science had not gained the attention of science education researchers, as such, the results of this research have considerable implications for postsecondary science programs. Drawing on a theoretical framework in which latecomers' identity trajectories accelerate towards or away from science as they are acted on by the dominant forces as well as by their improvisations with the available resources, the findings of this dissertation outlined in the preceding paragraphs suggest that latecomers' persistence would be better supported by making available a wider range of resources for identifying with science. The following discusses a variety of practical ways that such resources can be made more readily available, both at the classroom and the institutional level.

Implications for Practice: Providing New Resources for Identity Work

Part of the process of making more resources available for identification with science, is reducing the dominance of the current prevailing cultural models of the science program (e.g., the good grades model, the paradigmatic trail model, the teacher-centred model and the sink-or-swim model). As discussed in Chapter 2, the power of the paradigmatic trail model could be reduced by providing a variety of educational trails for all students to view. For example, the program could provide an interactive online form that generates a variety of possible course sequences tailored to each student's circumstances. Similarly, teachers can support alternative pathways by being careful of the assumptions they make about students' histories and educational trails and not making seemingly harmless decisions like skipping over foundational material because *most* students have already learned it in a prior course. Furthermore, a relaxing of academic probation rules for latecomers would permit latecomers to progress at a reasonable pace without the threat of institutional non-recognition that can destroy their inbound trajectories, thus reducing both the power of the paradigmatic trail model and the grades model. Also reducing the dominance of the grades model, teachers could use forms of assessment that weren't simply grades-based. Carolyn R. Cooper et al. (2004) found that forms of authentic assessment were powerful alternative resources for figuring success in science. The findings in Chapter 3 suggested that incorporating forms of alternative assessment (e.g., self and peer) can help dismantle the dominant figuring of teacher-as-evaluator, serving to get all students more engaged in their own learning of science.

Extending such suggestions to the broader picture, it was argued in Chapter 3 that teaching practices based on active learning and social constructivist approaches to learning would help reduce the dominance of the teacher-centred and sink-or-swim cultural models of learning and thus further support latecomers' persistence. That such a change to science teaching and learning at Island College and in other institutions where latecomers are trying to access and persist in science, would benefit latecomers (and other students) is well supported by the higher education literature. Seymour and Hewitt (1997) found that many students who leave the sciences in college, do so in large part because of a lack of active engagement in their courses. Calls for active learning approaches to postsecondary science education have been increasing as research continues to find that engaging students in the learning process and encouraging peer interaction enhances students' interest in and learning of science (Hake, 1998; Van Heuvelen, 1991; Wieman, 2007). However, as observed at Island College, these methods are largely ignored in favour of more traditional teaching methods such as lectures and recipe-format laboratory exercises (DeHaan, 2005; Handelsman et al., 2004; Wieman, 2007). Drawing from the findings of this dissertation, the proceeding discussions of ways to widen the array of resources available to latecomers suggest a variety of practices that take a more student-centred approach to learning than is currently the norm in postsecondary science.

Chapter 4 found that many teachers expressed a cultural model in which students were either assumed to be already interested in science or as not interested in science and thus as not belonging in the program. However, throughout this dissertation it was shown that despite wanting to succeed in science, it was not uncommon for latecomers to struggle to develop and/or maintain interest. Not having a strong history of positive experiences in science (e.g., in high school), some latecomers even accessed science because they had learned that science "opens doors," rather than because they were specifically interested in aspects of science. It may therefore be beneficial if administration and teachers make an increased effort to encourage students' interest in science. For example, as suggested in Chapter 2, programs could provide resources designed to excite and familiarize students with a range of science fields. Such resources might include a wider range of electives or guest speakers from a variety of science-related careers, perhaps targeted at latecomers. Also, as identified in Chapter 3, interest in science could be better supported by a reduction in the step-by-step approach to labs and greater emphasis on the problem solving and the exploratory nature of science (Teixeira-Dias et al., 2005). As hinted by this latter suggestion, active learning and social constructivist approaches to teaching and learning in general have been shown to also support student interest in science, while also supporting deeper learning and better academic results in postsecondary science education (Teixeira-Dias et al., 2005; Tsaushu et al., 2012; Wieman, 2007).

Another common theme that arose throughout the research was the importance of students asking questions to their success in, and identification with, science. As shown, the risk associated with asking questions (creating the possibility being recognized by others as not smart) is particularly high for latecomers, whose histories of mixed academic success means their science identity trajectories don't have the positive momentum associated with years of success in science. This suggests that many latecomers would benefit from environments in which asking for clarification or help from both teachers and peers is actively encouraged and is considered the norm rather than the more common situation in which students often have to interrupt a lecture to ask a question or wait until office e hours. Relating back to the previous recommendation on supporting students' interest, students' asking of questions was found to be a highly effective resource for increasing students' interest and active engagement in their own learning of science (Teixeira-Dias et al., 2005). Similarly, the findings of Chapter 3 suggested that by letting their students' interest and related questions guide them as to when and where to delve more deeply into topics, teachers can help all students engage more actively in their own learning.

Another important implication for practice that emerged across the embedded case study was that providing latecomers with opportunities to interact with each other in situations outside of the traditional classroom structure can provide significant opportunities for them to gain resources for identifying with science. The research presented in Chapter 2 found that such positive interactions can occur in a variety of settings (e.g., on Facebook, in the hallway, and on field trips). Such peer interactions also support the construction of solidarity, which was shown to be a useful resource for latecomers' continued identification with science. This is supported by a body of literature in which peers have been found to be an important resource for overcoming institutional obstacles to identification in the broader sphere of postsecondary education (e.g., Catherine R. Cooper, 2011; Espinosa, 2011). As mentioned in the previous section, the format of the online forums used in the first semester of embedded case study, brought together multiple figured worlds creating a third space in which some students were able to co-construct new ways to identify with science. Despite research showing the importance of such spaces of cultural production (Bretag, 2006; Hagiwara et al., 2007), these opportunities are rare in college science, and thus their use as a tool for supporting students' construction of inbound science identity trajectories is encouraged. Such spaces are most likely to be useful if teachers actively encourage their students to discuss their struggles in science (Barton, 1998), as was illustrated in Chapter 4.

Lastly, as earlier discussed, the findings of this study highlight that latecomers are not working from a purely deficit position, but instead already have acquired some resources with the potential to help them successfully identify with science. By encouraging latecomers to understand what these assets are and how they can support their progress in science, teachers could support their students' persistence. In keeping with the active learning and social constructivist theme of the implications for practice provided here, this could be accomplished by providing more types of activities that foster a wider range of talents, such as discussion, case studies, visual representations, and even games (B. F. Brandt, 2000).

Directions for Future Research

As the numbers of students following alternative pathways into and through postsecondary education continues to rise (Goldrick-Rab et al., 2007), it is increasingly important that research into latecomers to science be continued. The combined results of the three chapters comprising this overall embedded case study offer several suggestions for future research endeavours related to enhancing current understandings of latecomers' persistence in science. First, the present research program has provided a theoretically and methodologically coherent framework for exploring persistence through the concept of science identity trajectories and figured worlds. Future research might apply and extend this framework to continue the investigation into persistence in postsecondary science, as well as to explore other contexts in which this framework can be useful.

Also, the few opportunities to observe less traditional and more student-centred approaches to teaching (e.g., the non-traditional labs discussed in Chapter 3 as well as the online forum explored in Chapter 4), provided a wealth of useful insights into how latecomers' persistence might be better supported. Future research might further explore ways to widen the array of resources available to latecomers by studying identity work in post-secondary contexts in which active learning and social constructivist models of learning are the norm, rather than the more traditional models of the Island College science program.

Further, as discussed in the implications for practice, latecomers have already acquired resources with the potential to afford their identification with science. This emerging finding is worth exploring in more depth, as it offers a way of understanding latecomers that does not take a deficit perspective, but instead can highlight the ways in which their latecomer status can be used to promote rather than hinder their persistence. Such approaches (e.g., funds of knowledge and social capital) have been found to be very successful in supporting other types of marginalized students (Aragon & Kose, 2007; Cowie, Jones, & Otrel-Cass, 2011; Rahm, 2008; Seiler, 2013). Lastly, looking across multiple worlds that latecomers navigate may provide essential insights into students' learning and persistence, but has yet to be tried in-depth for latecomers to science (Catherine R. Cooper, 2011; Edwards & Mackenzie, 2008).

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