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Backtracking CTE Pathways: Identifying and Investigating Pathways and Critical Junctures in Two-Year Information Technology Programs

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Abstract

This NSF Advanced Technological Education (ATE) research and development project aims to design and test a Backtracking Technique for understanding the pathways students take through college and into careers in science, technology, engineering, and mathematics (STEM) and career and technical education (CTE), with the focus of this project on information technology (IT). The project gathers data about current and former students who started in the same cohort, includes institutional research data (e.g., grades, demographics, course-taking) and merges these data with employment data from surveys and lived experiences obtained from interviews. These data are analyzed to identify potential pathways and critical junctions that may lead to student success or other outcomes. The research team is led by a doctoral granting institution and a community college, and includes four additional community colleges that collectively serve rural and urban student populations.

In this paper we share the potential of the Backtracking Technique to generate contextualized career pathway data for institutions and create visualizations that can aid in institutional decision-making through a study pilot. The pilot is an initial effort to test the project's aims of integrating institutional data with phenomenological data to model student progression through post-secondary STEM programs. The analysis will identify and verify influencers that support or hinder student success. Quantitative data analyses will consist of descriptive and comparative methods, which will be verified and informed by open coding and thematic analysis of the qualitative data. We share how the systematic investigation of institutional and phenomenological data used in the Backtracking Technique has the potential to:
(1) generate practical knowledge about academic/career pathways in information technology for use by stakeholders; (2) identify and examine relationships among these pathways, students experiences, and psychosocial factors; and (3) add to the analytical methods available to institutional research professionals to document, investigate, and visualize student pathway information using data dashboards. This ATE project has great potential to transform the technician preparation for the advanced technology fields that drive the nation's economy.

1.0 Introduction

Institutional research (IR) data has long been considered critical for decision-making and planning in postsecondary institutions, and often conducted by institutional researchers in the roles of campus authorities, accountability technicians, and program evaluators; however, seldom has IR data been thought of as contributing to academic knowledge generation through the use of these data by IR academic researchers or academic researchers working in conjunction with IR technicians. Current, historical, and contextualized institutional and programmatic disaggregated data that has the potential to reveal key details about how students are performing in academic programs are often overlooked in favor of aggregated data. The tendency to aggregate, without exploring disaggregated data, also reduces the likelihood of finding key hindrances that disrupt student pathways or solutions that facilitate individual journeys.

Fallacies can also be formed when a limited scope or a narrow focus (e.g., a semester or academic year as opposed to longer periods of analysis) fails to disclose important elements of students' college experiences. Additionally, metrics on academic performance alone only measure the impact of formal education, but often omit the importance of experiential learning, student life, and employability as part of career pathways research.

Through a pilot of 10 African American students in IT, we explore how the systematic investigation of institutional and phenomenological data used in the Backtracking Technique has the potential to:
(1) generate practical knowledge about academic/career pathways in information technology for use by stakeholders;
(2) identify and examine relationships among these pathways, students' experiences, and psychosocial factors; and
(3) add to the analytical methods available to institutional research professionals to document, investigate, and visualize student pathway information using data dashboards.

2.0 Literature Review

Middle Skills IT Technicians are in High Demand, but Low Supply

The need for middle skilled IT technicians is exacerbated because related jobs are expected to increase by 18% by 2024 as the field evolves [1]. The shortage of skilled workers to meet employer needs creates an imperative for state and community colleges to produce the next generation of middle skilled technicians using the most effective, efficient, and innovative approaches. Over 2/3 of STEM students choose not to become IT students because they lack information, advice, and support in identifying IT career pathways [2]. With only two-years to produce middle skilled technicians, 2-year programs must adapt policies, programs, and practices that produce high retention, graduation, and completion rates, if they are to meet this vitally important undertaking.

The STEM Pipeline Leaks Diversity

The STEM pipeline is leaking its diverse participants. Gender, racial, and ethnic imbalance is particularly pronounced in IT degree attainment among STEM occupations. In 2013, women constituted only 29% of workers in these occupations, although they accounted for half of the college-educated workforce overall. Among STEM degree holders, the disparity was smaller but nonetheless significant with women representing 39% of employed individuals. Longitudinal researchers have strongly suggested that minority STEM students disproportionately experience critical academic and non-academic junctures that, without support, lead to their attrition [3]. Knowledge about how minority students successfully navigated the STEM pipeline from high school to employment, especially at the technician education program level, can ignite recruitment and retention in STEM fields, especially when these students experience employment upon degree completion. Figure 1 indicates that degree attainment in Computing and Information Services has shown little to no progress from 2003-04 to 2019-20, but as Figure 2 shows, Florida Computing and Information degree attainment has a downward trend in minorities' when considering minorities as a percentage of the college-aged population or the percentage of degrees/certificates.

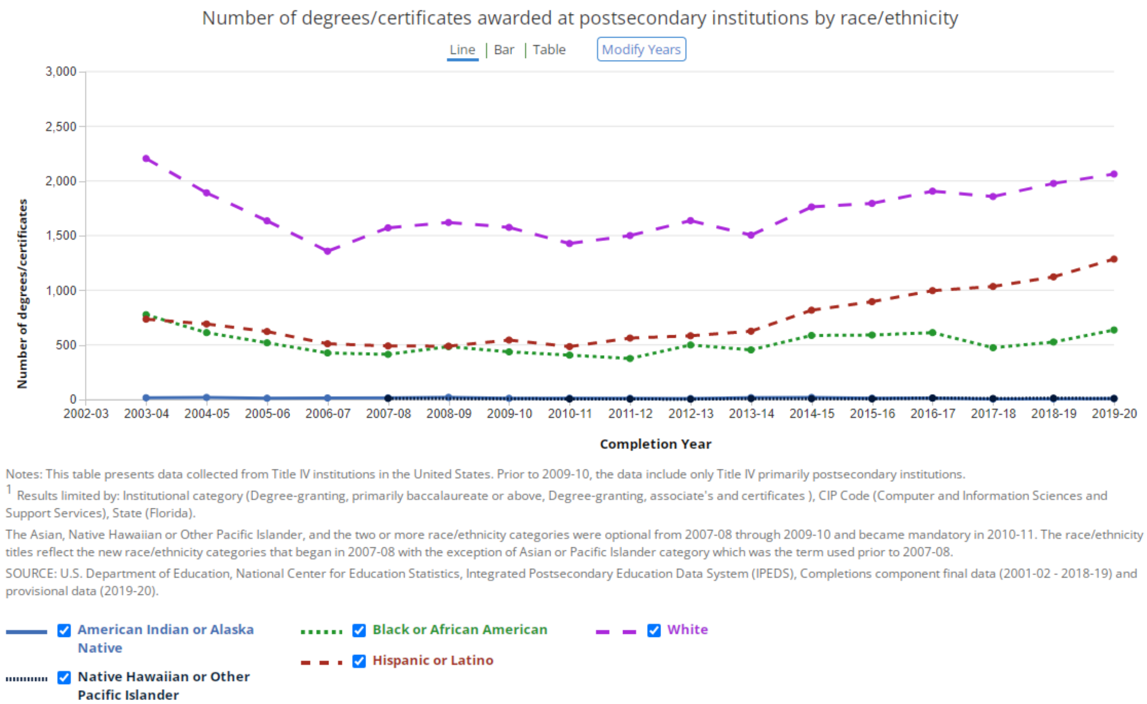

Figure 1. Number of degrees/certificates awarded by Florida postsecondary institutions by race/ethnicity in Florida [4]

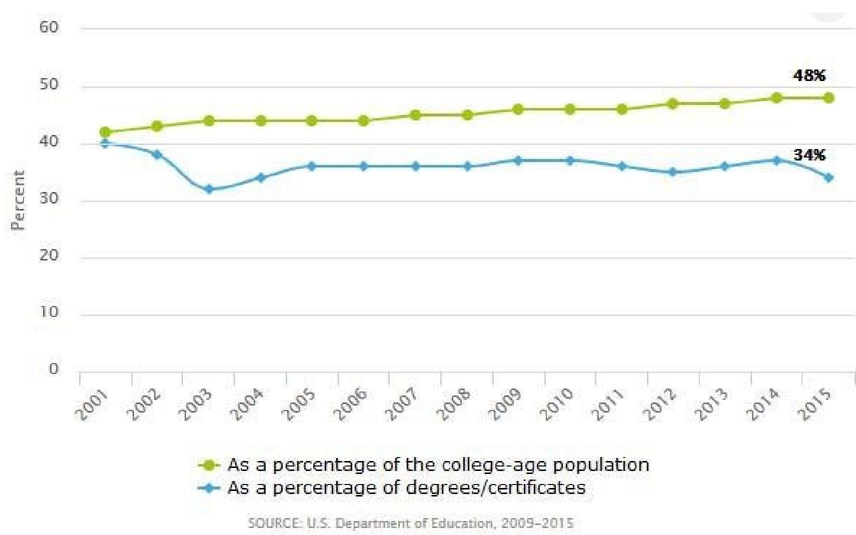

Figure 2. Underrepresented minorities in Florida Earning Computing Degrees/Certificates [5]

Figure 2's stagnant and declining rates suggest that more aggressive data-driven measures are needed to understand and adopt influencers that assist minority students in navigating the STEM pipeline and that Florida is a logical place to begin.

Community Colleges Reflect Diverse Students and Pathways to Technical Careers

Students who enter college to earn a 2-year STEM degree face many barriers in the multiple pathways to degree completion. The pathways that students are taking to prepare for middle skills technical careers are diverse and complex, with multiple entry and exit points and an increased tendency to earn credits from multiple institutions [6]. Challenges particularly affect students from underrepresented minority groups and women, as shown by the lower rates of degree completion by black, Hispanic, and female students, despite their interest on the rise [7]. The barriers are particularly difficult to overcome for students with limited experience with and knowledge of higher education, such as first-generation and low-income students. The number of students attending undergraduate institutions who have previous work experience, have taken a semester or more away from college, and have families is also increasing [5]. Students interested in technician education are navigating pathways in complex ways including combining credits from multiple institutions, transferring from 2-year to 4-year institutions (often without completing a degree or certificate), transferring from 4-year to 2-year institutions, enrolling at multiple institutions simultaneously or sequentially, persisting through lengthy degree attainment journeys, and taking college credit in high school through dual enrollment and advanced placement courses [8-10]. Identification of enabling or hindering factors and effective solutions affecting students' journey to 2-year STEM degrees and targeted efforts to improve student services, program, and policies based on this knowledge, will enhance the IT pipeline.

Institution-Specific Data Key to Unlocking College to Career Pathways

IR data are not used as frequently to identify and drive specific effective STEM program decisions [11, 12]. This absence of local data-driven decision-making affects all students, but mostly students of color [13]. Program completer data are not often used for programmatic decision-making because of low alumni survey response rates and a lack of resources to reach completers after graduation [14]. Without program level IR data, we cannot see student pathways, especially how students address critical junctures from college to employment. This project places pathway-related data to institutional decision-makers who can adopt, adapt, or institutionalize promising practices that can get more students from the IT AA or AS degree to direct entry in the workforce.

Critical Junctures and Employability Influencers Undocumented

Tinto's [15] conceptual schema for dropout from college indicates that institutional experiences in academic and social systems are key for improving student retention. Little is known about how formal and informal experiences (e.g., faculty interactions, extra-curricular activities, and peer group support) influence retention and outcomes, such as degree completion and employment [16]. Theoretical models and methods need to extend beyond completion outcomes to employment outcomes, in order to better understand the impact that all features of these programs have on IT students' career success [2]. Two-year STEM programs, whose students make an immediate impact on the economy, must include performance metrics that assess how well the program is imparting the appropriate employability skills that students need to be successful in the workforce and enrich local economic development.

3.0 Method

3.1. Design

Framed by Tinto's (1993) model of student attrition and persistence, the Backtracking Technique shown in Figure 3, employs a mixed methods sequential exploratory design [17] with multiple layers of data collection and analyses that merge and examine institutional data and alumni phenomenological experiential data.

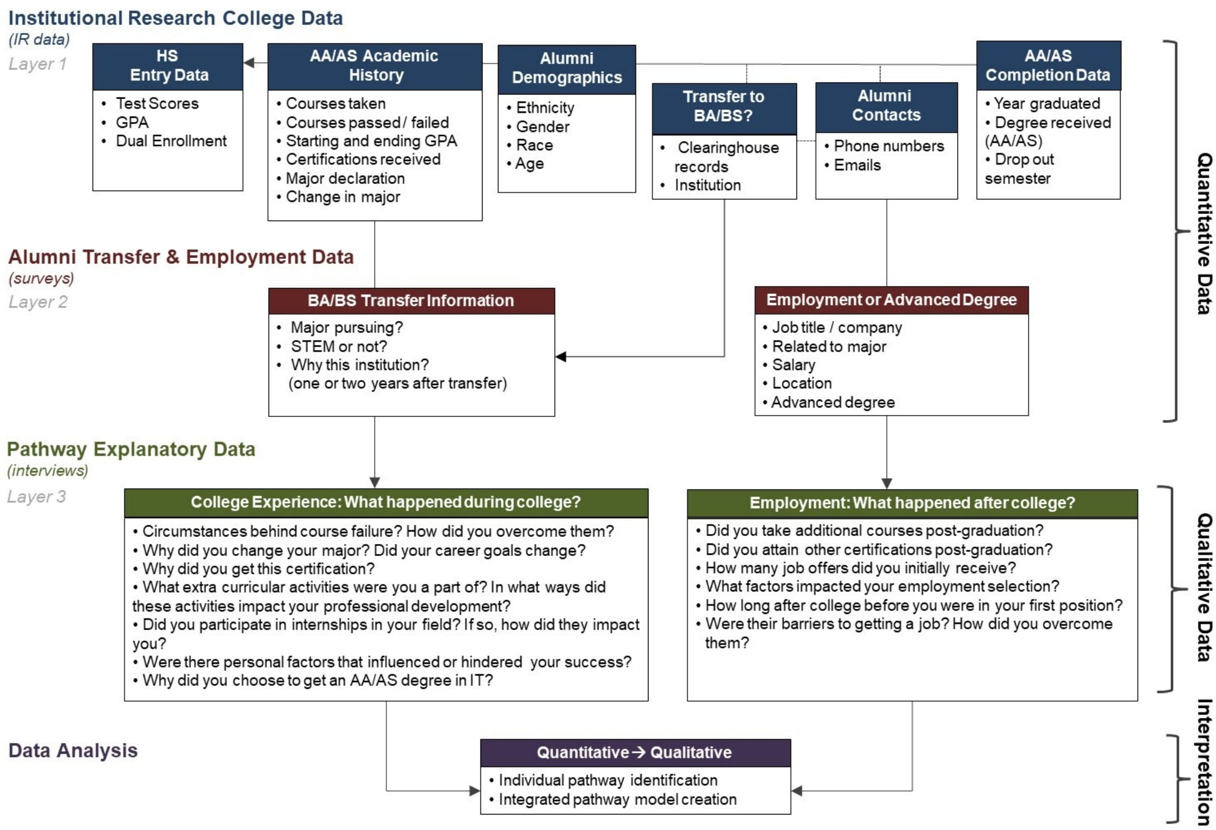

Figure 3. The Backtracking Technique

3.2. Data Collection

3.2.1. Participants.

To identify and obtain data on how the Backtracking Technique can be used to systematically investigate institutional and phenomenological data, we pilot the technique with 10 African American alumni who received their degree in Information Technology from a predominantly White institution in North Florida. Of the 10 students, 5 agreed to be interviewed as part of study to not only to understand their lived experiences but also as part of our goal to align their historical IR data, employment data, and student experiences. Of the 5 students who agreed to be interviewed, 3 consented to the release of their individual stories. All 5 students provided sensitive or personal information, but only 3 were comfortable to share those stories while remaining anonymous. Of the 3 participants, 2 were African American men (pseudonyms Robert and Aaron), 1 was an African American woman (pseudonym Christy), and 2 of the 3 were transfers with an Associate's degree from a community or state college.

3.2.2. Backtracking Layers.

The Backtracking Technique includes three layers of data collection.

IR and College Data (Quantitative) - Layer 1. In this layer, researchers with knowledge of Business Intelligence (BI) systems use institutional data of alumni to explore coursework (such as failed or low-performing courses, drops in GPA, and withdrawal from courses), financial aid, periods of non-enrollment, and changes in major. Once dashboards are setup and a student's ID entered, IR data has been collected, then exploration of the elements of the students pathway (i.e., preliminary analysis) can commence. In other words, IR data allows us to understand aspects of the students' academic history, and pinpoint areas where they may have been critical junctures, before students are interviewed.

For example, in Figure 4, the red circles depict that a student (in this case Christy) took a one-year gap in courses from Fall 2013 to Fall 2014, while in blue, there is indication that there was a change in major from Women's Studies to Information Communication and Technology when the student returned. There is also evidence that the student withdrew from all courses in Fall 2013. These types of observances are made with historical IR data and reveal a great deal of information about Christy's academic pathway and highlighted areas we should inquire about in her interview.

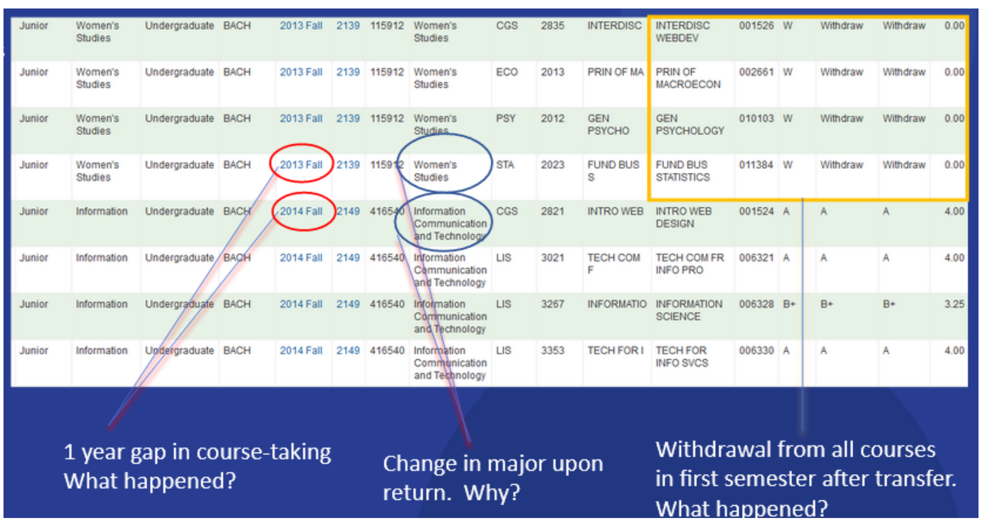

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Figure 4. IR Tidbits Example 1 (Course-taking, Change of Major, Withdrawals)

Figure 5 also shows another student (in this case Robert) who changed major from computer science to information technology, and that despite struggles with maintaining GPA (and 2 semesters of academic probation), the student was able to rebound and graduate.

Figure 5. IR Tidbits Example 2 (Change of Major, GPA and Academic Probation)

Alumni Transfer and Employment Data (Quantitative) - Layer 2. Layer 2 involves an alumni survey to capture employment or post-graduation outcomes data, with example questions provided in Table 1. Outcomes data, such as employment status, reason for job status, location of current position, whether the employment is in- or out-of-field, and salary ranges are a few of the data captured. Other questions include whether an advanced degree was sought, and if so, details on the advanced degree (e.g., whether the degree is STEM-related or not). Layers 1 and 2 are merged by student ID to align the historical IR and post-graduation outcomes data.

Table 1. Sample Alumni Survey Questions

Employment

- Please check the box(es) that describe(s) your current status.
  - ❑ I have a full-time job.
  - ❑ I have a part-time job.
  - ❑ I am not working because I choose to be unemployed.
  - ❑ I am not working, but not by choice.
  - ❑ I am not working (no reason provided).
- My job is located in ____(City)___, __(State)__. (Note: We added international location option).
- My job is in a field related to my bachelor's degree. Please check ☐ Yes or ☐ No
- My total annual salary is:
  - ❑ $16,000 or less, $16,001 to $32,000, $32,001 to $48,000
  - ❑ $48,001 or more, $64,001 to $80,000, $100,001 or more.

Pathway Explanatory Data (Qualitative) - Layer 3. Table 2 shares how interview questions are broken up into themes and how the generated questions are informed by layers 1 (IR historical data) and 2 (alumni survey) of the study, a strength of the Backtracking Technique. Participant samples are drawn to ensure there is appropriate representation of populations until saturation of responses is met and appropriate themes are identified. If intersectional research is desired, the appropriate demographics and saturation for each group (e.g., racial, ethnic, gender, degree type) should also be established using stratified and then random sampling.

The goal of the pathway explanatory data is to identify facilitators (factors that helped students), hindrances (factors that hurt or hindered students), and critical junctures (or stopping points that were detrimental to their success or required problem-solving to continue).

Table 2. Sample Interviewing Questions by Theme

- Course-taking
  - I see that you retook course X in Semester X Year X. What approach did you take to pass it the second time?
  - Did you feel prepared to take this course? Why or why not?
- Major/Degree Selection or Change
  - Why did you pursue this major?
  - Why did you change from X major to Y major?
- Mentoring/Advising
  - Were there any mentors, such as faculty or advisors, that had an impact on your college success? Provide examples.
  - How would you describe your academic advising while getting our AA/AS degree? After you transferred?
- Experiential Learning
  - Did you participate in internships or other employment opportunities related to your field?
  - What extracurricular activities were you a part of?
- Race/Ethnicity
  - What resources were beneficial to you as (a woman/person of color) while pursuing your degree?
  - Was diversity in your courses or on campus ever an issue? If so, how did you over these issues?

3.3. Data Analysis

3.3.1. Individual pathway identification and integrated pathway model creation.

For each student, there is a semester-by-semester story to tell that captures their college-to-career pathway. This involves identification of academic performance, experiential learning, student life, and employment outcomes in one snapshot. The models are created through the integration of the IR historical data, alumni survey, and interview data.

3.3.2. Integrated Pathway Model Creation.

There were several iterations of what individual pathway model integration might look like, from initial recordings to visualizations created through Power BI. We have learned that snapshots of student pathways are very powerful and can be used to tell important stories about students' experiences across many different points of interest.

4.0 Results

4.1. Individual Pathway Model Identification.

Table 3 illustrates how individual models can be summarized in snapshots by integrating the historical IR knowledge, employment outcome data captured from the alumni survey, and insertions about facilitators, hindrances, and critical junctures along the way based on student interviews. The quantitative data helps us to understand what happened, while the qualitative data helps us to understand why it happened. Both are critical to capture and understand student experiences. In the snapshot below, employment data is provided at the top, whereas black font denotes IR data, the green font indicates facilitators, the red font provides hindrances, and the blue font specifies critical junctures.

Table 3. Individual Pathway Identification

Participant 1, AA Woman, "Christy" Transfer: Miami Dade		Participant 2, AA Man, "Robert" Transfer: Central Florida College		Participant 3, AA Man, "Aaron" Traditional student, starting as junior	
Emp	4 jobs initially, currently <u>unemployed</u> – COVID delay, Miami ($0)	**Emp**	2 jobs initially, then <u>Tech Analyst Support</u> Manager, Palm Beach, FL (48-64K)		
Sem 7	Graduated, GPA 3.3	**Sem 7**	Graduated. GPA 2.8. HIND: Sick/Medical Issues	**Emp**	<u>Software Engineer</u>, California (100K and over)
Sem 6	Grades improve, medical under control, Part-time IT job	**Sem 6**	Grades improve. HIND: Sick/Medical Issues	**Sem 6**	-FAC: TA continues, FAC: Internship w/ current employer. FAC: Interview prep and networking with Code 2040, GPA 3.8
Sem 5	Grades improve, medical under control, FAC: joins IT club. FAC: Faculty mentor.	**Sem 5**	Grades improve, FAC: Part-time IT job, FAC: Faculty mentor. HIND: Family difficulties. HIND: Sick/Medical Issues	**Sem 5**	Superior Grades, Challenging Courses, FAC: Teaching Assistant in CS
Sem 4	Withdraws one course (HIND) due to medical (with Dean's approval for medical), remained enrolled.	**Sem 4**	Grades improve. HIND: Family difficulties.	**Sem 4**	Superior grades. Member/mentoring of Black Network Code 2040 group (FAC), FAC: Challenging Courses
Sem 3	**Major change = ICT.** Major , but still battling with medical (HIND).	**Sem 3**	**CJ: Major Change to ICT.** **CJ: Major medical issue. HIV Pos.** Received medical advice/care.	**Sem 3**	Superior grades. FAC: Competitive Internship #1 HIND: Struggles with ADHD
Sem 2		**Sem 2**	Challenges with courses.	**Sem 2**	***Major Change to CS***, felt courses not challenging enough. Felt CS majors make more $. FAC: Rotary Housing Scholarship
Sem 1	Major = Women's Studies. GPA 3.1. **CJ: Withdrew all courses. CJ: One year medical delay (diabetic coma)**	**Sem 1**	Major = CS, **CJ: Academic Probation (GPA 1.9).** HIND: Said not prepared for programming courses in earlier education.	**Sem 1 as junior**	Major: IT, 3.4 GPA HIND: Struggles with ADHD

4.2. Integrated Pathway Models.

4.2.1. Academic Performance Pathway

Backtracking allows us to explore GPAs across time, and the various starts and stops along the way. In Figure 6 we see that Aaron had a high GPA throughout and graduated early, while Robert did not perform at the same levels, but also had critical health concerns as shared in his individual snapshot.

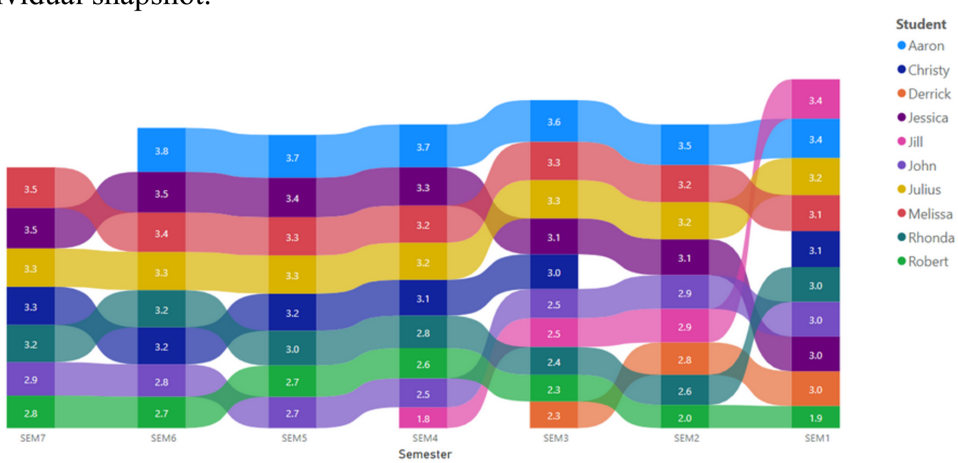

Figure 6. Upper Division Student Overall GPAs by Semester

4.2.2. Pathway Facilitators

There is also much to be learned about the facilitators that make success possible for students. For instance, in Figure 7, we see that part of Aaron's success (i.e., defined as GPA in this case), were the facilitators that he had from the beginning of his college journey. Aaron had scholarships, took rigorous courses (purposely), benefited from faculty mentoring and connections of his mentors, was a teaching assistant as an undergraduate student, and participated in development activities offered specifically for African Americans in computing. Robert, on the other hand, did not benefit from facilitators until his 5th semester, when he received advice from faculty mentors and also participated in a few IT clubs.

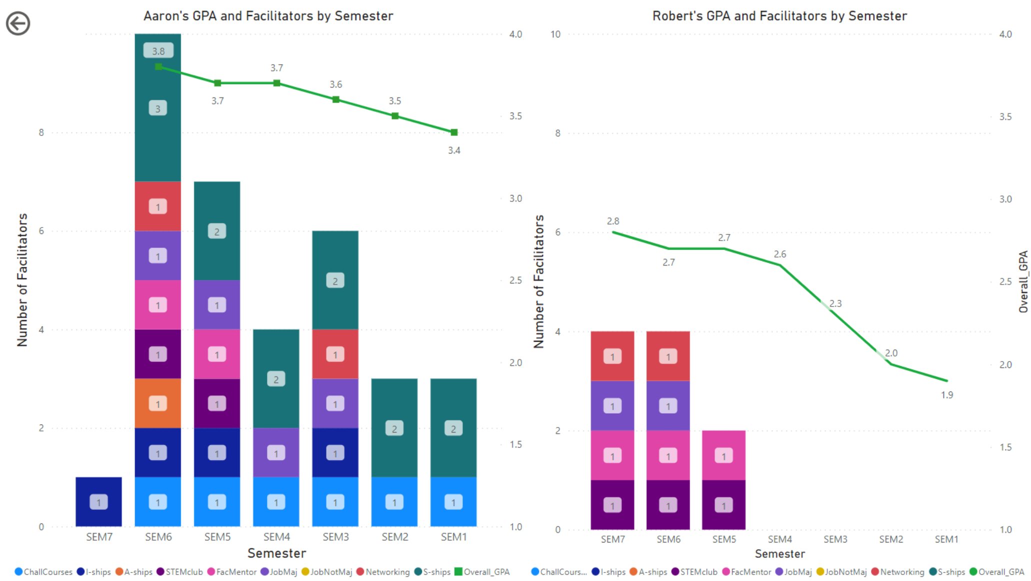

Figure 7. Pathway Facilitators by Semester

4.2.3. Pathway Hindrances and Critical Junctures

It is also important to remember that students experience hindrances in their academic journeys, which researchers might not often capture. Regardless of whether students are high performing, or barely making it across the finish line, students have obstacles to overcome. We know that Robert and Christy were faced with critical life-changing health concerns and both struggled financially to make it through college. It is also important to note that Aaron was in a one-parent household, in which he worked tirelessly to help him and his mom make financial ends meet, while he was a student. He also discussed a mental diagnosis which he has learned to overcome throughout his life. Figure 8 shows the weighing down of hindrances and the impact that they are likely to have on academic performance.

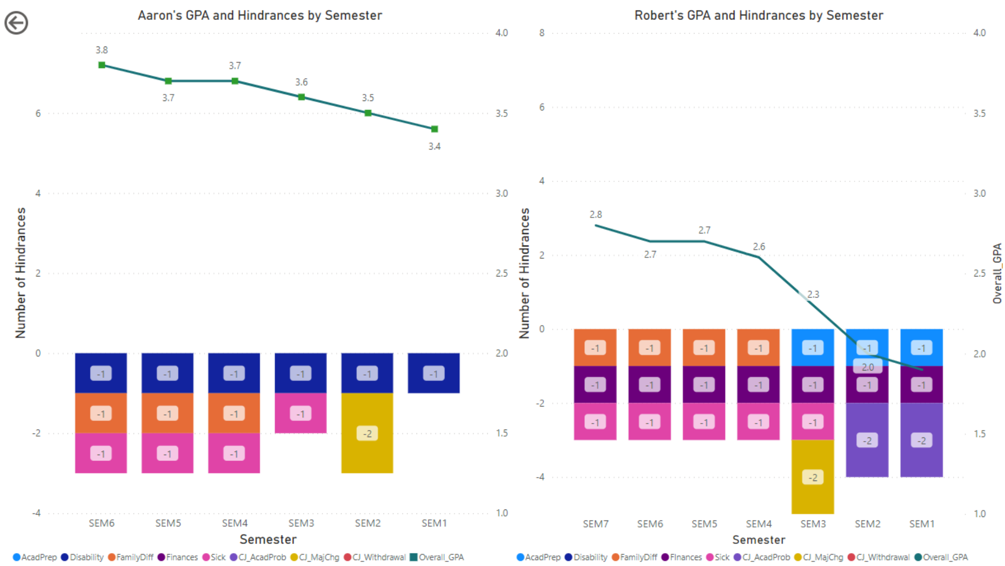

Figure 8. Pathway Hindrances and Critical Junctures by Semester

4.2.4. Pathway Employment Outcomes

Academic programs are accountable for the outcomes of their students, and the quality of their programs are often defined by employment outcomes. Furthermore, there are many outcomes for STEM majors that are important, but not applicable in other fields. For example, in-field employment after graduation is an important element of closing gaps for underserved populations in STEM, as gaps cannot be closed if underserved students who are trained and graduate in computing/technology do not obtain a position in their field. Figure 9 provides a visualization of students who graduate (maroon), are employed (purple), and whether they are employed in-field or out-of-field (yellow), with an adjoining map showing their placement. GPA is also portrayed (gray), along with salaries (Black).

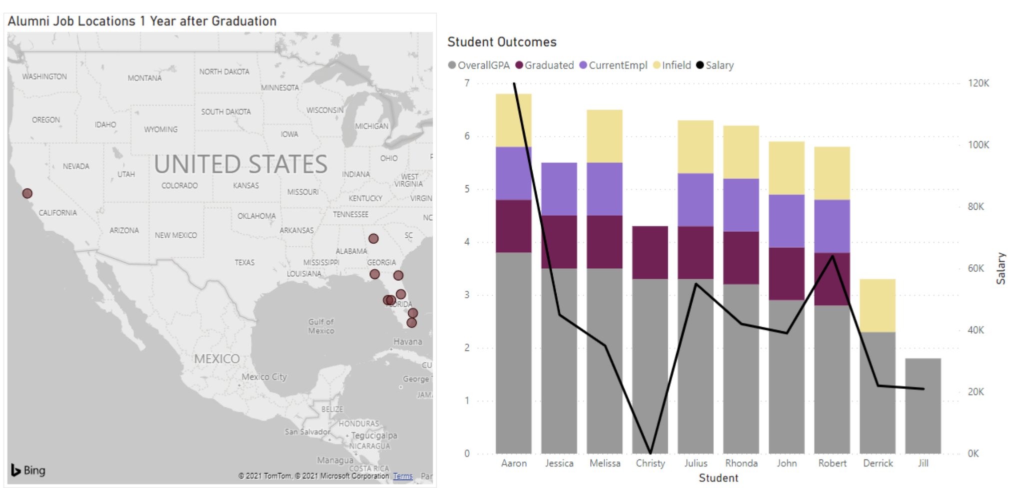

Figure 9. Employment Outcomes Medley

5.0 Findings

In this pilot, we sought to explore how the systematic investigation of institutional and phenomenological data used in the Backtracking Technique can serve to improve what we know about our students at our institutions and how to make decisions based on what we know about their experiences.

5.1. How does the Backtracking Technique generate practical knowledge about academic/career pathways in information technology for use by stakeholders?

Career pathways research is critical to our understanding of the totality of students' experiences, especially when these data incorporate and integrate factors that can help us to improve student recruitment, retention, graduation and employment outcomes. Through the Backtracking Technique, we learn that historical longitudinal data can be just as revealing as longitudinal tracking in the future, but most importantly that the combination of historical, current, and futuristic data collection is the most informative, and possible.

The Backtracking technique also focuses on students in programs at one institution, major or program, which provides the findings that are necessary to make decisions based on contextualized and individual data. Implications of these very specific student findings for stakeholders such as department chairs, deans, and program leaders reveal what is and is not working at the granular levels of programs, and potentially what formal or informal aspects of the IT curriculum to strengthen. Student academic advisors can also glean from the successes of other students and also use historical trends to highlight facilitators, hindrances, and even critical junctures that make student success attainable.

5.2. How does the Backtracking Technique identify and examine relationships among these pathways, students' experiences, and psychosocial factors?

Through the Backtracking Technique, the fusion of quantitative and qualitative data allow researchers to explore student life data that is often neglected in academic research, and perhaps ensure that there are programs that can ameliorate student concerns of health, belongingness, diversity, inclusion, and other cultural stereotypes and even racism. There is also much to be understood about the informal and experiential learning of students who participate in industry- and field-specific clubs, the importance of STEM faculty mentors, the value of trained and knowledgeable advisors, inclusion of industry to strengthen STEM programs, and factors that improve employability of students in a field.

Employment outcomes are one of the most rewarding and most telling of a program's success, and especially if tracking of students can continue for at least five years after graduation. This means that institutions must work to strengthen alumni tracking mechanisms to increase response rates and to establish relationships that ensure that alumni share their stories. Although it was not shared in this particular paper, exploration of those who have not completed academic programs are just as important as analyzing those who have. Programs must be leery of high retention rates, and explore data on those who are not being retained, in order to understand the conditions that are hindering these students' progress.

For those who complete programs, we learn the importance of capturing position data, salary data, and position location information to understand the reach of academic programs in delivering quality programs that actually have employment or continuing educational outcomes. These data also have the potential to yield important findings on the impact of STEM programs to local, state, and even national economies. For underserved populations, we can explore whether important gender, racial, and other gaps are being closed to meet the diverse and inclusive goals of the nation in STEM.

5.3. How does the Backtracking Technique add to the analytical methods available to institutional research professionals to document, investigate, and visualize student pathway information using data dashboards?

The integration of institutional research for academic knowledge generation by experienced technicians or academic IR specialists, and the use of historical data to catapult our knowledge of students' experiences are of instrumental importance to gain depth and even preliminary knowledge of the pathways that students have chosen or experienced.

Use of statistical and other visualization tools and software such as Microsoft Power BI and Tableau provide many avenues by which to visualize and share findings with institutional decision-makers, and both academic and professional audiences. Creation of data dashboards can immediately portray students' pathway experiences, but also serve as a useful tool for trained advisors or faculty mentors who seek to understand students' current or even past experiences.

6.0 Conclusion

The full potential of the Backtracking Technique is not yet understood, and there is much work that can be done to understand the depth of knowledge that can be gained by a longitudinal method that explores historical, current, and futuristic data. The deployment of a mixed and sequential method also holds promise for filling in gaps of knowledge of experiential learning, such as internships, clubs, faculty mentoring, and also programs that will allow students to successfully overcome the hindrances in the STEM pipeline. Continued exploration of the Backtracking Technique will allow researchers to understand the lived experiences of the whole student through disaggregated analysis, and then will the aggregation of these stories allow for important correlational, and even causal studies to unfold and further our understanding of what works for students pursuing STEM majors.

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