Supporting Underrepresented Students in Health Sciences: Using a Fuzzy Cognitive Mapping Approach

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Research Article

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Abstract

Background: The Students in Training in Academia, Health, and Research (STAHR) Program at the University of Missouri-Kansas City (UMKC) strives to increase the number of students from low-income families that have experienced educational challenges due to poverty who are prepared to enter, persist, and graduate from a health sciences degree program at UMKC. Students in the program participated in fuzzy cognitive mapping (FCM) sessions to ensure that all voices of the program were heard to improve program implementation, student success, and contribute to an equitable educational environment.

Methods: Fuzzy Cognitive Mapping sessions for the 2020-2021 cohort of students (n=52) were conducted to assess the strengths and weaknesses in program implementation, especially through the beginning of the COVID-19 pandemic. Students’ maps were coded by a team of researchers and then confirmed using confirmatory factor analysis.

Results: Statistical analyses reveal that mentorship, workshops, and social supports helped students to work toward their goal of obtaining a professional health sciences degree, while a lack of time, remote learning, and outside stressors inhibited their opportunities for success.

Conclusions: The findings from mixed methods analyses of mapping data demonstrate the value of this innovative approach to the field, especially when looking to incorporate student voice.

Background

In Missouri and nationally, students from low-income families who experience educational challenges due to poverty enter and complete health professions degree programs at low rates. In a cross-sectional study of self-reported race/ethnicity of US medical school graduates from 2002 to 2017, “numbers and proportions of Black, Hispanic, and American Indian or Alaska Native medical school matriculants increased, but at a rate slower than their age-matched counterparts in the US population, resulting in increased underrepresentation” (1). Further, students from lower socioeconomic backgrounds are less likely to persist through the first year of college, “less likely to persist to a bachelor’s degree or to have graduate degree aspirations” (2), and their aspirations specifically for pursuing advanced degrees in medicine or law are much lower than those of their higher socioeconomic peers (2). Although individuals who enter college as a means of social mobility often achieve some upward trajectory, this does not negate the extraneous experiences and pressures that a student with a low-income will encounter (2). These students, who are often the first in their families to attend college, may experience what researchers call a “cultural mismatch” with college environments that are designed with mostly middle-class students in mind; this can cause a sense of alienation and discomfort that impedes academic performance (3,4). When first-year college students have access to mentors and peer role models who support them to persist in their studies and connect them with necessary resources, the outcomes improve (3).
The Students Training in Academia, Health, and Research (STAHR) Program was established in 2019 to meet the needs of first-generation students, students from underrepresented socioeconomic backgrounds, and students at risk of not persisting to graduation. The program achieves this goal through structured pipeline programs, which include hands-on experiences, academic support and supplemental instruction, student psychosocial and emotional development, financial literacy training, and mentorship. The Program focuses on supporting students by providing additional programming and curriculum to overcome social barriers, such as feelings of disconnectedness and unease with the larger collegiate and/or programmatic community. These barriers have become more imperative due to the COVID-19 pandemic. Globally, students have expressed high distress levels, low engagement, and confidence in their academic performance and professional development in the wake of the COVID-19 pandemic (5,6).

To identify aspects of the STAHR Program that best facilitate students’ success from the perspective of the students themselves, we utilized Fuzzy Cognitive Mapping (FCM) as a new approach to analyze barriers for under-resourced students in health sciences, whose needs are often overshadowed by other priorities, further leading to cultural mismatch (4). FCM is an evidence-based methodology proven as a reliable knowledge-based model that facilitates “sense-making” by helping program participants communicate strategies and decisions (7,8). Researchers developed these maps as a tool for capturing and modeling the behavior of qualitative system dynamics (9). Further, FCM helps us capture the intuitive knowledge of the students in the program and helps develop a multi-layered understanding of the critical components and processes within the program that support students to become successful in their program. FCM has been applied in a vast array of fields, such as improving agricultural policy design (10), assisting business leaders with their strategic management functions (11), knowledge sharing in urban planning (12), and understanding students’ quality of interaction within online learning in higher education (13). Overall, FCM develops an integrated, cross-sectoral understanding of complex systems by aggregating semi-quantitative mind maps from multiple agents (14). Utilizing FCM allows us to analyze program successes and limitations from the student’s perspective, thus creating a program tailored to students’ specific needs from year to year. To demonstrate the FCM methodology and its usefulness in program evaluation efforts, this paper will overview the FCM study conducted through idea mapping sessions with the 2020–2021 cohort of STAHR Ambassador students.

**Methods**

**Procedure**

The research team conducted 13 virtual mapping sessions with 52 STAHR students over three weeks during the month of April 2021 via Zoom (Zoom Video Communications, San Jose, CA). Each session consists of three to five students. In preparation, all researchers were adequately trained to facilitate mapping sessions with students. Additionally, team members were trained in coding and analysis procedures to ensure consistency throughout the evaluation process.
Each mapping session was facilitated by two researchers; at the beginning of each session, students were presented with a blank map. The blank map displays a center circle as the program goal, five ovals on the left side for facilitators to the goal, and five ovals on the right side for barriers to the goal. Before the mapping sessions began, students were assured that their responses would be held confidential and no identifiable information would be shared with the Program. First, we reminded students that the goal of STAHR is to ensure that students in the Program successfully complete their health science degrees, which is the center or destination of the map. Second, we asked students to fill three to five ovals on the left side of the map with activities, practices, or policies within the STAHR Program that facilitate the attainment of the program goal. Third, we asked students to fill three and five ovals on the right side of the map with activities, practices, or policies within or outside of the STAHR Program that create a barrier to the attainment of the program goal. Fourth, students drew directional arrows between ovals representing a connection between concepts and the overall goal. Finally, students rated the strength of each connection using a scale from one to three, with “1” being a weak connection, “2” being a moderate connection, and “3” being a strong connection. Figure 1 is an example of a completed map.

Participants

A total of 52 students participated in mapping sessions in the Spring of 2021. Of the participating students, 59.6% (n = 31) were reportedly enrolled in the medical program, 25.0% (n = 13) in the pharmacy program, and 15.4% (n = 8) in the dental program. Most participants were female (80.8%, n = 42) and were reportedly citizens of the United States (92.3%, n = 48). Almost forty percent (40.4%, n = 21) were Black/African American, 25.0% were Asian (n = 13), 19.2% were Caucasian (n = 10), 7.7% were multiracial (n = 4), and 7.7% reported their race as “other” (n = 4). Additionally, 21.2% of students (n = 11) were reportedly Hispanic or Latinx. Half of the students reported that English was the primary language spoken at home (n = 26), and 32.7% of students reportedly spoke a language other than English (n = 16), or a mix of English and another language (n = 1), when at home. All students reported being full-time students, and 11 students (21.2%) reported part-time employment. Table 1 provides the demographic information of the students.
Table 1
Participant Demographics; STAHR Ambassador students (n = 52) at the University of Missouri-Kansas City, 2021.

<table>
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<td>Is English your primary language spoken in your home?</td>
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The University of Missouri-Kansas City Office of Research Services determined that this study is 'Not Human Subjects Research,' therefore exempt from Institutional Review Board review, as it was considered to be a program evaluation activity. This was determined on May 18, 2019, via reference/protocol number 18–380. However, the research team provided written and verbal informed consent in line with the Declaration of Helsinki to student participants before each mapping session.

**Analysis**

**Coding**

The research team started with item-level analysis, examining the concepts (i.e., facilitators and barriers) on the maps. Four team members carefully read through the maps and developed a codebook based on relevant and recurring themes found in students’ responses on the ovals (see Additional File 1). Together and using an inductive process, the research team finalized nine codes for facilitators and eight codes for barriers. Once the codebook was agreed upon by all four researchers, the 52 total maps were divided among two teams, each of which consisted of two researchers. Each team coded two groups of maps based on the codebook, discussed any discrepancies, and reached a consensus on the codes assigned to each map.

**Statistical Analysis**

Following the coding process, we used Microsoft Excel (Microsoft) to create an adjacency matrix for each map. An adjacency matrix is a matrix that represents a network-type diagram or graph, directed (with arrows) or non-directed (without arrows) (8). We used the directionality of the connecting arrows and the strength score assigned to each connection to develop each adjacency matrix. For better results in the analysis and easier interpretation, we normalized mapping data using min-max normalization technique to put the strength scores in a range between 0 and 1. We then merged the individual matrices into one data set, which is exported to an Excel-based program called FCMapper (beta version, www.fcmapper.net) for further analysis. Centrality is the key measure from FCMapper results and is calculated by summing the absolute values of arrows. Centrality is a measure of the importance of map concepts; therefore, concepts with high centrality indicate a high impact.
Although FCMapper is helpful in investigating the network of responses using a single data set, this process does not confirm or validate the network structure using a statistical model. Therefore, using the same data, we employed confirmatory factor analysis (CFA) to confirm the underlying structure of the mapping data. As a part of the Structural Equation Modeling (SEM) family, CFA plays an essential role in model validation (15,16). CFA helps us understand the relationships between the mapping concepts and the underlying structure for supporting our students’ success in professional-level health degree programs. Analyses are conducted in R (R Core Team, 2021) and lavaan package (Rosseel, 2012).

CFA Model Fit

Two model fit indices were used to determine if a CFA model fit well with the existing data. Chi-square statistic and Standardized Root Mean Residual (SRMR) were also used as one of the absolute fit statistics (SRMR < .4); SRMR represents the standardized difference between the observed and model-implied variances and covariances (17,18). In addition, Root Mean Squared Error of Approximation (RMSEA) is commonly used for comparative fit (19). It compares model fit to a perfect model and is expected to be smaller than .05. We also used a Comparative Fit Index (CFI), which indicates a close fit (CFI > .95), and Tucker-Lewis Index (TLI), which denotes a perfect fit (TLI > .95) to best prioritize the needs of STAHR students (17,20,21).

Results

FCMapper Results

A total of 52 maps were completed by students in the STAHR Program. We used 17 broad themes to code the maps. Nine of these concepts “facilitate” the program goal, meaning that they increase the likelihood that students will be successful in completing a professional health sciences degree and in the program. Eight of these concepts were “barriers,” meaning that they decrease the likelihood that students will be successful in completing their professional health sciences degree or in the program.

The facilitator concepts were ordered by their centrality (see Fig. 2). The net influence of a variable in a cognitive map can be understood by calculating its centrality (C), which shows how connected the variable is to other variables and the cumulative strength/weights of these connections. When using the fuzzy cognitive mapping technique, a variable can be more “central” although it has fewer connections if the connections carry larger weights or are stronger (8). Essentially, “the centrality of the variable is not only a frequency of expression but also [exemplifies] how important that variable is given the whole structure of the cognitive map” (22). In a similar fashion, “barrier” concepts were ordered by their centrality, as seen in Fig. 3.

To better interpret the results, we identified the top five facilitating concepts and the top five barrier concepts captured by students’ cognitive maps. The most impactful facilitator to student success was “Mentorship” (n = 46, C = .88), characterized by mentorship experiences involving both faculty and
students. Students shared experiences that benefited them throughout the year such as being matched with a mentor within the same field of study, one-on-one meetings with mentors, and an overall sense of compassion and encouragement from their mentor. The second most impactful facilitating concept was “Workshop/Meetings” (n = 45, C = .69). Students expressed that workshop topics, such as monthly STAHR meetings with different professionals who gave refreshing perspectives, were helpful to their career and professional development. The third most impactful facilitator was “Social Supports” (n = 26, C = .46), in which students identified facilitating concepts such as feeling a sense of belonging with other peers in the STAHR Program, support from friends and family, and welcoming STAHR staff to guide them through the challenges of being a first-generation or minoritized student.

Conversely, the most impactful barrier to success in STAHR Program was “Time” (n = 31, C = .55), which included experiences such as overlapping and conflicting schedules between class or clinical schedules and programmatic requirements, as well as balancing and managing their time as a graduate-level student. The second and third most impactful barriers were “COVID-19/Remote Learning” (n = 29, C = .41) and “Stressors/Outside Stressors” (n = 23, C = .41); these concepts ranked equally in responses. Regarding “COVID-19/Remote Learning,” students shared that the decrease in activities due to COVID, Zoom/technology fatigue, and fewer opportunities for clinical experience hindered their capacity for success. For the “Stressors/Outside Stressors” concept, students expressed that tensions between balancing school, their personal lives, familial expectations, financial responsibilities, health issues, and feelings of homesickness were sometimes too burdensome, especially as low-income, educationally challenged, or first-generation students who often carry more external pressures than their peers.

**CFA Results**

We conducted CFA with the weights and connections on the maps to investigate the variables that facilitate or hinder student success. The two-factor model, with the “facilitator” and “barrier” as its individual latent variables, had an excellent fit, $\chi^2(19) = 19.73, p = .41$, CFI = .98, TLI = .97, RMSEA = .03, SRMR = .08. These results indicated that the top three impactful facilitating variables were 1) Workshop/Meetings ($\lambda = .80$), 2) Social Supports ($\lambda = .54$), and 3) Mentorship ($\lambda = .50$), which is consistent with the above-mentioned results. Five variables were retained in the “barriers” factor, with the top three being 1) Lack of Engagement ($\lambda = .56$), 2) Outside Stressors ($\lambda = .49$), and 3) Workshop/Meeting Barriers ($\lambda = .44$). Overall, the CFA analysis results are congruent with the results from FCMapper software (see Fig. 4). Figure 4 displays the factor loadings of variables to the construct. The larger the factor loading is, the more impact a variable has on the construct. Overall, combining the results from FCMapper and the CFA, in addition to the other concepts identified by FCMapper, we added “Lack of Engagement” to our final list of significant barriers in the STAHR program. Students who mentioned “Lack of Engagement” shared feedback about lacking one-on-one opportunities for mentorship, networking, or bonding with mentors.

**Discussion**
What matters to students?

Mentorship. The FCM approach helped the program understand the urgent needs of students from low-income families experiencing educational challenges due to poverty. The results indicated a few critical factors that contribute to or hinder STAHR students’ success in progressing from one year to another, obtaining a health sciences degree, and having a career in the field. As found in other research studies, many students from all walks of life find mentorship helpful, whether it’s from faculty or upper-level students (23). The STAHR Program encourages students to have in-person meetings with their mentors at least once per month, if not more frequently, and to have additional virtual meetings if feasible. Based on the mentor-mentee encounter data reported by students during this cohort, a majority of their encounters (81.4% out of 117 encounters) were virtual (via Zoom, Teams, or phone). Topics for discussion included academic/professional development, psychological development, identity development, social development, and leadership development. Over 20 professional mentors served as direct support or a liaison for their mentees in relation to these support areas. In that sense, it is imperative that the mentors are adequately skilled to ensure that they are able to meet their mentees where they are at, build a trusting relationship early on, and tailor support to the individual’s needs. In turn, it is also essential to assess and understand the well-being of the mentors to ensure that mentor-mentee relationships remain a productive priority within the program.

Stressors. Conversely, students experience stressors that hinder their success in the STAHR Program and within their health sciences degree. Time management is challenging for STAHR students, as they have to juggle between coursework, clinical rotations/shadowing, and employment, unlike many of their peers who do not need to rely on their own employment to finance their education (2). In addition, students sometimes find themselves in a difficult situation where they are worn out from meeting virtually but are also unable to attend the in-person meetings because of their schedule. It is important for a program to understand the context it exists in and strike a balance between virtual meetings and in-person activities (e.g., workshops); our study shows that students appreciate when a program makes an effort to accommodate their schedules. Likewise, students reported experiencing financial difficulties. Given the social background of STAHR students, it is important for the program to understand that these students might be working hard to make ends meet for themselves and possibly for their entire family. As a result, students face additional stress in balancing their numerous conflicting priorities while participating in all program activities, which illuminates the need for additional support surrounding time management and workshop participation. Acknowledging this reality, the STAHR Program provides scholarships to students who actively participate in the program so that their financial stress may be lessened.

Furthermore, many of the barriers and stressors students experienced can also be attributed to the COVID-19 remote learning environment that caused feelings of a lack of engagement between students and the program. As students adapt to a new mode of learning, it is still important for programs and institutions that work with students to care for students’ mental health, monitor their anxiety and stress levels, and make sure that psychological/social supports are provided in a timely manner. Students need person-centered, holistic support; it is unrealistic to assume the only support they will require when obtaining a
health sciences degree is purely academic. For example, studies show that students benefit by receiving support in developing a sense of belonging to the professional field, as well as support in developing their professional identity (24).

Implications for Incorporating Student Voice

The present study employed the fuzzy cognitive mapping technique as an exemplary tool for researchers and evaluators alike who aim to seek out the voices of those with lived experiences in a program to better understand the facilitators and inhibitors of program or participant success. In the field, there is always a struggle to provide inclusive and equitable support to students from underrepresented backgrounds. It is invaluable for a program to take into consideration students’ real needs (voices from students) and make modifications to tailor its support to student’s needs while meeting program goals. By doing so, the program promotes increased involvement and retention of students, which can then lead to better program outcomes.

Limitations and Future Research

One limitation of the study is that program outcomes were not included in the study. Given the scope of this study, factors directly related to outcomes were not investigated. Future research will focus on how the support students receive contribute to program outcomes, including academic performance, program, and school retention, post-graduation employment, etc. Another limitation of the present study was the sample size; however, in the future, we hope to increase the sample size and examine the results on the subgroup level, based on race, ethnicity, gender, income-level, and any other identifying factors that may lend itself to useful analysis. In order to better understand whether student needs vary by demographics and to create programs that are suited to these students’ needs, it is advantageous to increase the sample size in order to complete analyses at the subgroup level.

Conclusions

Fuzzy cognitive mapping offers researchers a mixed-method approach that computes suggestions for improvement while allowing for aspects of programs that work to remain intact. Our study found that through the 2020–2021 academic year, the most helpful factors STAHR Program provided were mentorship from peers and mentors in the community, workshops aimed to support their academic growth, and social support from the program and from their community. Alternatively, students struggled with balancing time between school and other programmatic obligations, being in a remote environment due to COVID-19, dealing with outside stressors, a program structure reflective of the program’s infancy, and misdirected workshop topics. In turn, the barriers identified by students were particularly valuable in pointing out the blind spots in the program implementation and directing areas for future program evolvement.

Abbreviations

C Centrality
Declarations

Ethics Approval & Consent to Participate: The University of Missouri-Kansas City (UMKC), Office of Research Services determined that this study is Not Human Subjects Research, therefore exempt from Institutional Review Board review, as it was considered to be a program evaluation activity. This was determined on May 18, 2019, via reference/protocol number 18-380. However, the research team provided written and verbal informed consent in line with the Declaration of Helsinki to student participants before each mapping session.

Consent for Publication: Not applicable.

Availability of Data and Materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests: The authors declare that they have no competing interests.

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References


Figures
Figure 1

Sample of a Completed Map—A sample concept map used in fuzzy cognitive mapping processes, like the ones used in the STAHR Ambassador and Academy evaluations at the University of Missouri-Kansas City, 2021.
Figure 2

*Measures of Centrality for Facilitating Concepts* – Concepts that facilitate students’ success in their health science degree and their corresponding centrality measure, as calculated during the FCM mapping study conducted at the University of Missouri-Kansas City in 2021.
Figure 3

Measures of Centrality for Barriers— Concepts that inhibit students’ success in their health science degree and their corresponding centrality measure, as calculated during the FCM mapping study conducted at the University of Missouri-Kansas City in 2021.
Figure 4

*CFA Two-Factor Model* – The most impactful facilitators and barriers to student success after conducting a CFA two-factor model analysis, as calculated during the FCM mapping study conducted at the University of Missouri-Kansas City in 2021.

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1.pdf