Predicting STEM Employability for Disadvantaged Young People

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***Abstract*— Employability research typically adopts one of two incomplete perspectives, focusing on either individuals' suitability for work or external labor market opportunities. However, young people seeking jobs and those seeking to help them, such as counselors or program developers, need to consider both the individual and the market perspective. The present research integrates elements of both frameworks to create a quantitative model of one aspect of employability, its interplay with STEM education. That model will use simulation methods to predict the success of programs designed to improve employability through enhanced STEM education. The model's inputs will be drawn from the empirical research literature, augmented by expert elicitations from community leaders and members to interpret those results for specific their settings. I propose a holistic approach to STEM employability, quantitatively analyzing personal and contextual factors and relationships between them. The project scope is focused on a Pittsburgh neighborhood. However, by assuming a holistic view, it enables applications to other individuals and organizations. Integrating previously isolated fields studying employability, the research reflects interactions between individual characteristics, personal circumstances, and external factors, ultimately contributing to recommendations on labor market policy and community development.**

Keywords—employability; STEM; mental model; labor; development

I. INTRODUCTION

STEM enrichment programs engage students in career development, providing support that can include summer employment, after-school enrichment programs, and organized internships. Despite these efforts, employability remains a serious problem in neighborhoods suffering from disinvestment and economic decline. Researchers have studied many factors affecting employability, looking at both labor markets and the skills and experiences that young people bring to them. This study builds on these frameworks to synthesize that research and characterize one aspect of employability, its interplay with STEM education.

Employability research typically adopts one of two incomplete perspectives, focusing either on individuals' suitability for work or on external labor market opportunities. Studies of individuals focus on personal characteristics potentially affecting the probability of employment in existing labor markets [1]. Studies of those markets focus on factors such as barriers to entry [2], [3]. The limits to these studies reflect the limits to the sciences involved, none of which have methods that can take all factors into account. However, young people seeking jobs and those seeking to help them, such as counselors or program developers, need to consider both the individual and the market perspective. The few attempts to integrate results from these potentially complementary accounts have been primarily conceptual, describing how various factors might interact, but without providing guidance on their relative importance. (e.g., [4]).

This study characterizes employability and its interplay with STEM education, incorporating both the individual and market perspectives in a quantitative model that uses simulation methods to predict the success of programs designed to improve employability through enhanced STEM education. The model's inputs are drawn from the research literature and augmented by expert elicitation to interpret results for specific settings and fill in gaps in the research.

My primary research question is "How do the factors that researchers have found to influence STEM employability combine in the specific conditions facing individuals in post-industrial neighborhoods experiencing economic decline?" Answering it will allow us to address the practical question of "How can employability in these settings be improved through STEM education?" The answers to these questions will directly inform the design of such programs and indirectly inform policies for economic and community development.

The present demonstration of the approach focuses on programs offered by one community development organization in a low-income neighborhood in Pittsburgh that has yet to benefit from Pittsburgh's revitalization after the decline of the steel industry. However, the holistic approach allows applications to be relevant to other individuals and organizations.

The research actively synthesizes scientific research and professional experience with the goals of (a) predicting the impact of enrichment programs on employability, considering both individual and market demand issues as they apply for specific individuals and jobs; and (b) developing communication and consultation mechanisms with the communities they are meant to serve.

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II. The Approach

This study uses a mental models methodology, which combines formal analysis, descriptive research, and design, systematically focused on the needs of the intended audience and application. At its core is a formal model into which real-world elements are mapped [5]. We first create an expert model represented by an influence diagram, here focused on the employability of young people from low-income areas, and then use a computational model to apply our findings to the specific local situation with the goal of predicting STEM employability. Our analysis introduces the influence diagram as a graphic synthesis of current research into a single diagram, describing employability as a function of relevant factors and their interdependencies. The influence diagram is then represented by the computational model, enabling numeric representation of employability factors and sensitivity analyses. The computational model summarizes existing research, based on our review of the literature and consultation with experts in the field.

After creating the initial employability influence diagram, employees and volunteers from the community development organization were asked to participate in expert elicitation interviews to review the model, tailor it to their circumstances, and estimate its parameters. All interview participants have experience working with elementary, middle, and high school students from a Pittsburgh neighborhood. The interviews began open-ended, designed to elicit participants' beliefs about employability in their own terms, and led to final judgments eliciting subjective probability distributions. These probability distributions predicted employability, based on scenarios of interest for specific individuals, programs, jobs, and labor markets.

The estimates will facilitate creating the most relevant programs, by helping young people, and those advising them, to understand the cost, risks, and benefits of the resultant programs, so as to know how to invest their time, hopes, and energies. Finally, we discuss ways of communicating the content of these analyses to community members, so that they can acquire realistic expectations of program costs and benefits, as well as convey their concerns to program developers.

III. Theoretical Framework

The expert model of employability used here combines personal factors, related to individuals seeking employment, with external factors, related to their social and economic setting. The result is a holistic model where these elements and their relationships are quantified, allowing predictions for the success of programs and individuals. Hillage and Pollard emphasize personal factors including individuals' readiness to work, employability assets (human capital), presentation (demonstrating the assets), and deployment (career management skills) [1]. Van Der Heijde and Van Der Heijden elaborate on this perspective, with a competence-based approach that treats employability as a continuous process [6]. Their approach focuses on individual's capabilities, not the individual's employment status [7], [8]. Complementing these personal factors, the demand side of employability refers to contextual factors beyond the individual's control, particularly labor market and employer conditions.

The present approach follows McQuaid and Lindsay's introduction of a comprehensive framework for employability [4]. They argue that a broad framework is essential to characterizing employability, capturing both employer demand and labor market supply, along with personal aspects of those potentially seeking work, such as family and caring responsibilities. Their "holistic" framework of employability includes three components that influence an individual's employability: individual factors (such as employability skills and attributes, demographics, and job seeking), personal circumstances (such as household circumstances, work culture, and access to resources), and external factors (such as demand factors and enabling support factors). In our model, these three components provide the model's top-level structure, which are elaborated through factors drawn from leading employability literature and instantiated for student STEM employment in Pittsburgh.

IV. The Expert Model

The expert model translates theoretical statements from the research literature into a formal model that (a) presents them in a visual and understandable way, offering insight that is immediately useful to decision makers; (b) can support quantitative predictions of the success of programs and individuals, described in terms of the model; and (c) allows describing the mental models of different stakeholders in comparable terms [5]. The present expert model uses an influence diagram, a Bayesian formalism that can accommodate knowledge from diverse sources [5], which is particularly useful given the differing theories for factors affecting employability. Common employability factors were added to the influence diagram and concluded when new employability theories were already represented by the influence diagram.

Each node in the model represents a factor that can enhance or limit an individual's employability. There are three groups of factors: (a) individual characteristics that affect the ability to find and sustain employment, such as their assets (skills, knowledge, and attitudes), mobility, and demographics; (b) personal circumstances that encourage or hinder employability, such as socioeconomic factors related to social and household circumstances; and (c) external factors, reflecting the demand side of employability (e.g., labor market rules and regulations). As mentioned, the framework is adopted from [4], a holistic approach that integrates both the supply and the demand sides of employability. Fig. 1 shows key factors affecting these three main factors, based on a review of the research literature cited above. An individual's employability is predicted as a function of the factors in the model. A group's employability is the distribution of those predictions over its members. The impact of a program (or event) would be captured in predictions with and without that event.

Individual characteristics include four factors: (a) *Assets* (or "human capital") include the knowledge, skills, and attitudes that employers value in a prospective employee [1], [9]. (b) *Mobility* includes characteristics related to being willing and able take positions. They include occupational mobility (moving from one job to another), geographical mobility (physically moving locations), and financial mobility (managing the costs of changing jobs [10], [11].

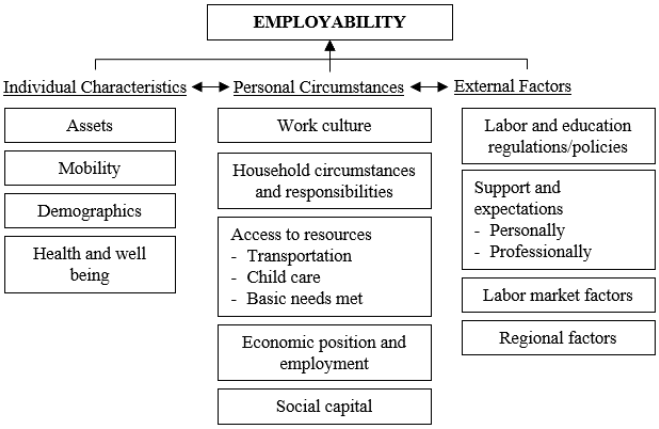

Fig. 1. Top-level influence diagram describing employability as a function of three attributes: individual characteristics, personal circumstances, and external factors.

(c) *Demographics* include factors that could affect an individual's ability to take a job or employers' likelihood of offering one, for reasons of suitability or (positive or negative) discrimination [12], [13]. They might include age, gender, nationality, country of origin, time in host country, ethnic group, religion, language, or culture. (d) *Health and well-being* include physical health and ability, mental health, disability status, and related factors affecting individuals' ability to fulfil a job, given available accommodations [14], [15].

Personal circumstances include five contextual factors relating to the settings in which individuals live and work: (a) *Work culture*, including the professional communities, personal relationships, peers, and local communities that can encourage and support taking and keeping jobs. (b) *Household circumstances and responsibilities*, including direct care for dependents, other family commitments, and access to safe, secure, affordable, and appropriate housing [16]. (c) *Access to resources*, including transportation (proximity to public transit, owning a car and paying for gas), child care (personal or family support, financial commitment), and basic needs (necessary food, appropriate clothing) [17]. Other factors relating to personal circumstances are (d) *Economic position and employment* (current employment situation) and (e) *Social capital* (social and interpersonal networking that corresponds to career opportunities) [17]–[19].

External factors refer to the demand side of employability. They include external factors such as (a) *labor and education regulations and policies*. Examples include income support for unemployed individuals and skill development and job search assistance. External (b) *support and expectations* includes personal support and encouragement and professional support through established job search and employment policies. (c) *Labor market factors* refer to the effects that employers and institutions have on the employment, such as job quality, employment quantity, and recruitment practices. (d) *Regional factors* include the economy, societal culture, local labor market, peers, and colleagues.

V. The Computational Model

To achieve computability, the attributes from the influence diagram are represented as four employability factors: assets, ability to work, support, and labor demand. These four factors represent a simplified version of the top-level model, used to reduce confusion in the elicitation interviews. Table 1 demonstrates how the top-level factors are represented in the computational model.

TABLE I. Four computational factors, represented by a series of factors from the top-level model.

Employability Factor	Description
Assets	Knowledge, skills, and attitudes that employers value in potential employees
Ability to work	Mobility, health and well-being, household circumstances and responsibilities, access to resources, economic position and employment
Support	Work culture, demographics, regional factors, support and expectations from the labor market, social capital
Employment demand	Labor market factors, labor and education regulations/policies, regional factors, demographics

Each of the four attributes is modeled from expert responses, which were used to create a triangular distribution for each computational factor and were aggregated into a single employability prediction. All attributes are weighted to give an overall employability score, and these weights may be elicited to better represent specific situations. For example, in "elite" job interviews, it is vital for students to connect to their interviewers and find cultural similarities [20], so in that case the *assets* and *employment demand* factors would have a heavier weight for the student.

VI. Expert Interview Protocal

The interviews had two parts, first eliciting qualitative feedback on the expert model and then eliciting quantitative assessments of the variables in the computational model. Both parts of the interviews were open-ended, designed to elicit participants' beliefs about employability in their own terms, reduce cognitive biases, and focus on issues found relevant in the research. The questions were designed to be answered by individuals who do not have experience formally. expressing their beliefs, even when they are experts in the subject matter [5].

The first part of the interview consisted of open-ended questions, aimed to identify potentially important factors influencing student employability and relationships between the factors from the community leader's point of view. Participants first openly described factors they think influence student employment, answering, "What is the first thing you think of when a student is seeking employment?" The interview then continued to specific questions ("Tell me about opportunities offered to students through [your organization], and what students gain from attending"), where participants responded in the context of their circumstances and responsibilities within their organization.

The second part of the interview gathers quantitative judgments of employability in the context of students in their organization. Using a scale from 0 to 100, participants were asked to give a lower bound, best guess, and upper bound for their students for each of the four factors in the computational model. The scale was treated as absolute, where scores of 0 and 100 were represented in hypothetical, extreme scenarios. Participants were provided with a

reference sheet describing the computational factors and defining a score of zero and a score of 100 for each factor. Interviewers described a youth "on the job training" apprenticeship program at a national technical company to help define what was meant by STEM employment during or after high school.

Interview requirements included a familiarity with students at a community-based organization and a base knowledge of STEM fields and factors that help students get employment in those areas. The mission of the community-based organization involves strengthening the community through working with families and youth on the social, academic, and economic factors. We interviewed five experts, all staff members. Interviewed staff had positions in administration, as directors, and as coordinators who work directly with youth and families in the community. Throughout the interviews, all experts demonstrated a familiarity with the youth, programs offered, and goals and motivations behind the organizations and actions of the organization.

VII. Results

Participants were first asked a series of practice questions designed to ease them into using the scale from 0 to 100 points. The interviewer provided qualifications for the specified apprenticeship program and described hypothetical students at the lower extreme, upper extreme, and middle of the scale. All experts reported reasonable probabilities for the students getting an interview at the apprenticeship program, providing valid reasoning and probabilities for the average student and mostly reporting 0% and 100% for the students at the extremes of the scale.

Experts were asked to consider individuals who have strong and weak employability characteristics for each computational factor, and to provide an upper bound ("student who has strong [employability factor]"), best guess ("best estimate of a typical student"), and lower bound ("student with the lowest [employability factor]") for students at their organizations, as well as an average best guess for local students not in their organization. Fig. 2 displays responses from the five experts for each computational factor. Expert 3 did not provide a quantitative employment demand score, stating that they didn't have enough background in this area to answer.

Within the constraints of the small sample, several trends emerge in the experts' responses. First, estimated upper and lower bounds of the students are broad. Experts were asked to consider all students that were at their organization, reporting scores of students who had the strongest and lowest factors that correspond to employability. When explaining their reported score, Expert 3 stated, "We have one hundred, and we have zero, and we have fifty, and we have everything in between." Similarly, broad ranges were reported by other experts, although not as extensive as the range from 0 to 100 points.

Another trend in the experts' responses is that their best guess is higher for students in the program than for students not in the program. For example, for all four factors, Expert

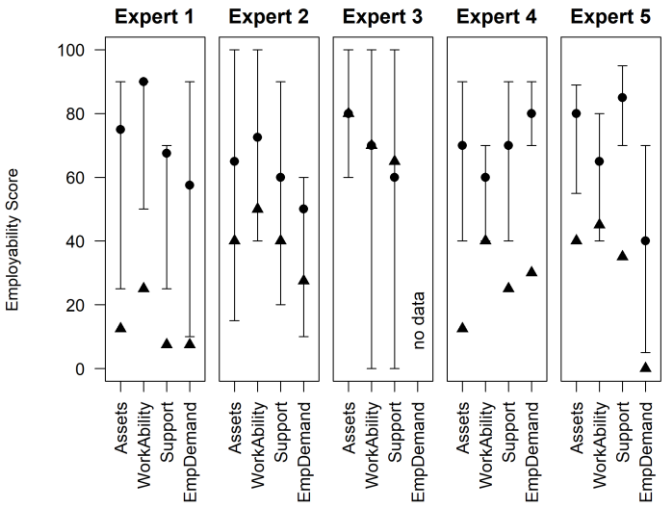

Fig. 2. Elicited employability factors for each expert. Vertical lines represent the range of possible scores for students in the program and circles represent the expert's best guess. Triangles represent the mean reported best guess of students not in the program.

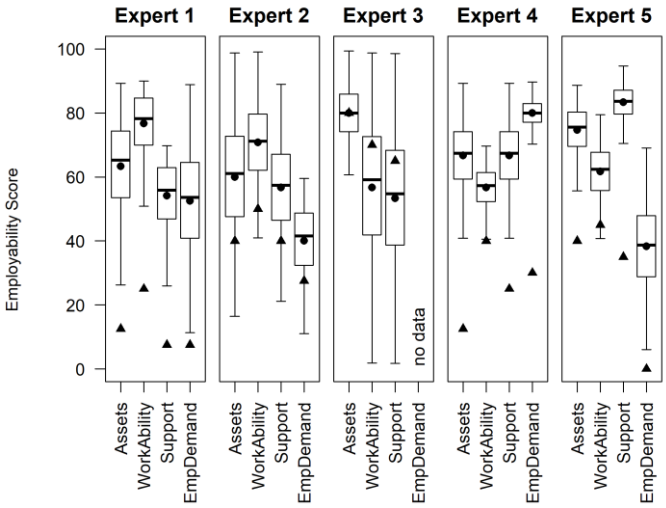

Fig. 3. Box plots of triangular distributions from reported employability scores. Vertical lines represent the range of possible scores for students in the program, bold horizontal lines represent the median, and circles represent the mean. Triangles represent mean reported scores of students not in the program.

2's best guess for students in the program is 20-25 points higher than their best guess for students not in the program.

It was too demanding to ask respondents for explicit probability distributions corresponding to their reported employability scores. However, they alluded to the distribution of students along their range. For all the experts, their "best guess" tends to be on the high side of their range, suggesting distributions that are skewed to the right. This was emphasized by one expert, who noted that their lower bound represents "a very small number of students, and when I say small number, I'm talking about one or two, and that's out of, for this particular group that's out of 40."

Individual triangular distributions are generated using the lower bound, upper bound, and best guesses from the experts, shown in Fig. 3. The reported best guess (shown in Fig. 2) was always higher than the mean calculated from the aggregated distributions, incorporating a lower bound that may have represented very few students. Expert

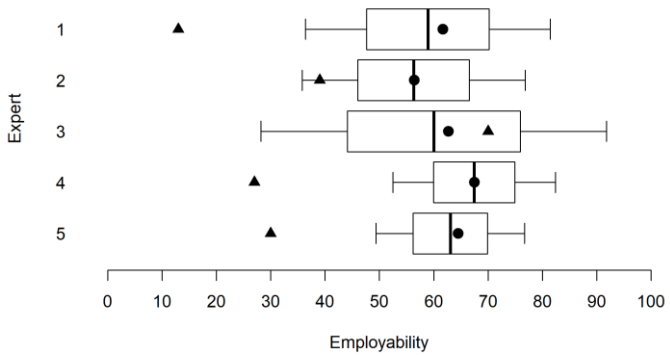

Fig. 4. Box plots representing employability cumulative probability distributions elicited from community experts, aggregated from equal weighting of employability factors. Horizontal lines represent the range of possible scores for students in the program, bold vertical lines represent the median, circles represent the mean, and triangles represent the aggregated employability scores of students not in the program.

perception of the students in the best guess scores was also skewed more towards a score of 100 than is represented by the triangular distributions, perhaps from a tendency for leaders to see positive potential in their students. One expert noted, "We just seem to get like real gifted, talented students, I don't know how. I'm not being biased."

These triangular distributions were weighted equally and aggregated to generate cumulative distribution functions for each expert's responses, shown in Fig. 4. The distributions are mostly symmetrical and continue to represent a high amount of variance in the reported scores. For all experts excluding Expert 3, average employability scores for students in the program were higher than for students not active in the program. When asked how a student in their organization compared to "typical Pittsburgh students outside of [their organization]", the Expert 3 responded, "they're [students in our program are] all typical Pittsburgh students." However, Expert 3 went on to explain that "if they come here, plus [their score increases] … If they don't come here, neutral. But if they come here, not negative." Like Expert 3, the other experts stated that if the student attends their program their score will not decrease. One expert also noted that students have left the program and "…their grades have gotten worse and their school attendance has obviously gotten worse. And so, and their skill levels just aren't even close to where the students that have been in the program the entire year are."

A. Reported weighting and overall employability

Fig. 4 used equal weighting when aggregating the employability factors because that has been found to be more robust than clinical judgement [21]. We also asked experts to assign weights to each of the four employability factors. Table 2 shows results. *Assets* was rated as important by all but Expert 3, reflecting the others' emphasis on skill development, resume building, and interview skills. This view is in line with the research literature, which tends to have an individual-centered outlook on employability.

All experts but 3 assigned 20% importance to the ability to work factor, with their explanations emphasizing the roles of financial limitations and access to transportation. Ability-to-work issues are frequently addressed in labor market policies.

TABLE II. EXPERT ASSIGNED WEIGHTING FOR EMPLOYABILITY FACTORS, WHERE EACH EXPERT WAS ASKED TO "DISTRIBUTE THE 100 POINTS ACROSS THE FOUR FACTORS."

	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**
Assets	30%	40%	12%	30%	30%
Ability to Work	20%	20%	12%	20%	20%
Support	20%	20%	51%	25%	10%
Employment Demand	30%	20%	25%	25%	40%

The support weighting had the highest variation between experts with a 41% gap between Expert 3 and Expert 5. Expert 3's weighting was the most distinct, emphasizing "guidance and mentoring… knowledge of self, positivity, and moving forward," and placing more than half of their weighting on support. But while Expert 5 rated support the lowest out of the four factors, they still acknowledged its importance by saying how it is organically engrained as part of the organization: "If they're just in the program, that's, they'll improve [their support score]."

All these community leaders appreciated the effects of employment demand on student employability, even if those factors were out of their control. One expert describes their outlook as teaching students how to succeed within their external environment, saying, "You can't really necessarily control the system that you have to navigate. But you can navigate the system. So, we try to teach them what that means."

In addition to these judgments of relative employability (in the range defined by the lowest and highest student envisioned for each scale), we concluded the interview by asking for judgments of absolute employability scores, for all students at their organization, as defined by the "probability of making the 'short list' for the Harley-Davidson apprenticeship program (being seriously considered for the job, not accounting for other candidates)." Table 4 shows these reported best guesses for students in the program and for students not in the program, and their differences between the distribution mean.

Reported weighting and equal weighting produce similar estimates, with the two weighting techniques differing from each other by a maximum of three points. There is less variation in the best guesses of students in the program compared to students not in the program, students in the program range from 65 to 80 (15-point difference), while students not in the program range from 28 to 70 (42-point difference).

VIII. DISCUSSION

The mental model approach, which structures interviews around a formal model of the domain, allowed these experts to express their views about STEM employment in their specific context in terms that could be compared to the model and to one another. The experts even noted in the interviews that this structuring of employability issues was helpful to their thinking about employability and internal program evaluation.

Although structured around the four factors in the computational model, the interviews allowed participants to explain their views in their own terms. Several themes emerged in those explanations. With respect to individual characteristics, there was a heavy emphasis on assets, particularly in resume and interview preparation, knowing what jobs are in the labor market and how to apply, self-confidence, and self-awareness. Racial demographic factors were emphasized by all experts, particularly as a source of discrimination affecting later employment. Three important factors brought up under personal circumstances were personal support from parents, access to transportation, and economic position.

For external factors, experts mostly discussed employment quantity, speaking about the lack of jobs in the neighborhood and especially in the STEM field. When speaking on the quality of jobs available, one expert noted, "high quality of work, I mean that doesn't really, doesn't really exist." Another expert elaborated, mentioning that there is a lack of available STEM jobs for high-school-level students: "I think that for this employment demand, that's pretty reflective across all high school students… it's not really indicative of students in our programs being much worse off."

In their quantitative judgments, experts described large ranges in students attending their program. These differences partially reflect differences in their perceptions of the relative importance of various employability characteristics, particularly for the four employability factors. The interviews used two strategies to reduce variability in experts' understanding of the questions: (1) referring to a specific apprenticeship program as an example of what it means to have high STEM employability in high school, and (2) providing a reference sheet describing each employability factor and what was meant by a score of 0 and 100. The apprenticeship program and the reference sheet provided a common ground and language for discussing the experts' experience and observations.

A uniform distribution for the experts' responses was used to evaluate uncertainty in the expert responses, representing their distributions as a function of their upper and lower bounds. Overall, this lowered the overall employability score from an increased emphasis on the experts' lower bounds. The experts were optimistic about their students, mostly giving best guess scores that were above 50 and towards the upper range of their estimates, and this response characteristic was lost in the uniform distribution. Sensitivity in the expert responses could also be evaluated through varying the reported weights from the experts and comparing the output to results from equal weighting. This will be completed in later analysis.

IX. Conclusion

Overall, this research integrates results from previously isolated fields studying employability, quantitatively integrating both personal and labor demand factors into an employability model that expert community leaders, policy makers, and academics can all understand. Knowledge from community experts was systematically assembled and its implications for STEM student employability can be further investigated under specific circumstances. This research treats employability as reflecting potentially complex interactions between individual characteristics, personal circumstances, and external factors, ultimately contributing to recommendations on labor market policy and community development.

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