# Final Design Report: MaxMatch

## Prepared for:

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## June 7, 2023


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## Sponsored by:

- Design Thinking and Communication Program
- Professors Egel and Dubrow
- McCormick School of Engineering and Applied Science
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# Executive Summary

In an ideal world, all students regardless of gender, race, ethnicity, and other attributes should have equal opportunity to an exceptional education. However, this is not the case in many areas around the world, including Evanston school districts. The achievement gap between students of color and white students in Evanston is prevalent and ever-growing, especially since the termination of Project Excite. Project Excite was a program founded by Evanston teacher Dr. Vondracek in 1998, and it was a supplementary educational program accessible to students of color in Evanston. The program was for students of color ranging from 3rd to 8th grade, and the main intention was to help these students who were falling behind their white peers become on par with them by the time they reach high school. However, Northwestern University was the primary funding source for Project Excite, contributing approximately 80% of the funds; so when they ceased funding for the program, Excite was forced to shut down. Thus, our team's task has been to create a program to do the job that Project Excite set out to do; provide academic, social, and emotional support to students of color, helping them attain the self-confidence and discipline to want to learn and seek higher education.

We needed to create something that required low funding and was not something that would be too logistically difficult to create. It also needed to be easily accessible to its primary users - tutoring programs. So, with these things considered, we created Max Match.

Max Match is a tool that tutoring programs can use to efficiently pair students with tutors. It consists of a matching algorithm that is powered by two main components: a research quiz and student/tutor questionnaires. The research quiz is the tool used to determine the weights and values of the questions on the matching questionnaires. It is given to a sample population of students in Evanston, asking them questions about what they value most in their education. The data from this quiz is gathered and used to determine what questions and answers in the matching questionnaires should be most appreciated when pairing a mentor and a mentee, meaning that the questionnaire will be tailored to each group of students. Finally, the data from the mentor and mentee questionnaires is inserted into the matching algorithm as inputs, which are used to create the mentee-mentor pairings between the students and tutors. Thus, our matching algorithm will create highly suitable and compatible matches between a student and a tutor, and mentees of color will be provided with the academic, emotional, and social support they need to gain the self-confidence needed to pursue their passions and goals.

# Introduction

Our project sets out to bridge the education gap in Evanston public schools. Minorities in America, economically disadvantaged people, consistently perform worse in school, often setting them up poorly for the rest of their lives. One popular solution to help bridge this gap is to offer free tutoring programs. Our project aims to help these tutoring programs by creating more effective pairings between tutors and students. The most popular way to pair tutors and students currently is either manual pairing or random assignment. Instead, our solution surveys each tutor and student to determine what type of pairing is best for them.

Our solution, called MaxMatch, works in a three step process. First, we distribute a research quiz to members of our target community to learn generally about what they value in a student/teacher relationship. We then create a questionnaire to learn about the specific tutors and students in our program. We take the data about each student and tutor in our program and use it to create match scores between each tutor and student. Finally, we enter these match scores into our pairing algorithm to generate the optimal pairings between students and tutors.

The purpose of this report is to describe the pairing process and detail how a tutoring program would adapt it to its operations. The information consists of a description of our users and their requirements, an explanation of our rationale behind picking our solution, and a few options for future development.`

# Users & Requirements

## Introduction

Our design is a systematic matching algorithm that works to pair an older mentor, such as a high school or college student, with a young student of color and take them on as a mentee to tutor them academically and, more importantly, provide them with the emotional and social support they need to pursue their interests and goals. This algorithm is intended to be suitable for tutoring programs to pair mentors and mentees efficiently.

## Users

- Tutoring Programs
- Students in the tutoring program
    - Pre-high school Evanston Students, ages 8-14 years old
- Tutors
    - ETHS students/Northwestern students, ages 18-22 years old

# Reasons of Use

## User Scenarios:

**Student of an elementary school in Evanston:** George is an 8-year-old, African American boy who has trouble focusing and is struggling in school, especially in math and science. George comes from a low-income family, so his parents lack the resources to get supplementary social and academic help and guidance for George. Eventually, George's parents discover this tutoring program that efficiently matches mentors and mentees and looks easily accessible to get George the help he needs.

**Northwestern Student:** Mellie is a 19-year-old, African American woman who is in the School of Education and Social Policy(SESP) at Northwestern University. For experience for her major and aspiring career, Mellie is looking for work to tutor and educate young students in Evanston over the summer, and her professor made her known of this tutoring program that is looking for mentors to volunteer and tutor lower income, underperforming students of color who are looking for help.

**Tutoring Program:** The tutoring program will implement the MaxMatch algorithm - whose Design Concept and Rationale are thoroughly explained in the next section - to efficiently and optimally match a mentor with a mentee.

## Major Requirements

- Program requires low funding to operate
- Program is easily accessible to low-income, students of color in the Evanston community
- Program is easily advertised and marketed to its target audience
- Program strongly engages young students of color in academic endeavors
- Program fosters social and emotional well-being and support for students of color
- Program implements a curriculum that aligns with the regulated curriculum of the school districts, while is still personalized to a struggling student's needs

## Explanation of Major Requirements

- **Require low funding for implementation:**
    - It is ideal that this program is easy to implement in terms of funding, and it does not require a significant amount of financial resources to be sustainable.
- **Be accessible to low-income families:**
    - The users of this program are mainly from low-income families, thus it is essential for the program to be easily financially accessible for the families of struggling students of color.
- **Be Marketable:**
    - It is essential for the families of students of color to hear about this program to know that there are resources available to help their child, that way they can actually sign up and join the program. This could be done through advertisements in their school such as by letter mail, emails, or an announcement from teachers.
- **Foster Academic Engagement:**
    - Young students need to truly want to be a part of this program and be eager to learn, not simply do it for supplementary academics that they are forced into, as then, no effort will be exerted. It needs to be a program that is amusing and enjoyable for kids while still offering academic support.
- **Provide Social and Emotional Support:**
    - It is imperative for this program to foster social and emotional support in participating students of color. This will give them the confidence they need to gain a passion for learning and to further pursue and advance their academic goals as they mature into their secondary education. It is important to show and assure these students of their full potential.
- **Synch with School Curriculum:**
    - While it is important to slow down and create personalized lessons to teach struggling students through their most optimal learning methods, it is still necessary for the curriculum of this program to stay on track with the school curriculum, that way the student will not fall further behind their peers. This could be done by focusing more time on challenging subject areas for a student and

subsequently taking away only minimal time from subject areas that a student already understands.

# Design Concept and Rationale

## Overview

MaxMatch is a tool used by tutoring programs to match tutors and students. It consists of a three-stage process: a research quiz, questionnaire, and matching algorithm. We designed this process in order to match tutors and students in a way that promotes social and emotional growth as well as academic success.

- It begins with a Research Quiz which informs program administrators what students in a given area value in an educator.
- Then, a Questionnaire is used to query prospective tutors and students about their own hobbies and values.
- Finally, our Algorithm analyzes the weights produced by the Research Quiz and the data from the Questionnaire to produce a combination of tutors and students that prioritizes the highest cumulative match score.

The following sections provide a more in-depth description of the Research Quiz, the Questionnaire, and the Algorithm with a discussion of our rationale.

## Research Quiz

The research quiz is the tool used to determine the weights and values of the questions on the matching questionnaires. The research quiz is given to a sample population of kids in Evanston that asks them questions about what they value most in their education, gathering this data for the matching questionnaires. The data from the research quiz is then used to determine what questions and answers in the mentee and mentor questionnaires should be valued most significantly when pairing a mentor and a mentee. This is done by weighting certain categories by how frequently they appear in the answers to the quizzes.This means that the questionnaire will be tailored to each group of students in a given area. There are two different quizzes, one for kids and one for those in eighth grade or older. The difference between the two is a more in-depth identity question about the student's teacher.

## Rationale

Our basis for the research quiz rests on the assumption that a tutor-student relationship is not significantly different from a teacher-student relationship. We are comfortable making this assumption because under ideal conditions, a tutor would fill the same role as a teacher but just in a one-on-one setting. This means that if we want to create a successful tutor-student relationship, we need to figure out what makes the relationship with a teacher work. This is why we use the research quiz to find out what students value in their favorite teacher. Theoretically, the set of values for a given geographical area should be similar, so if we determine the values

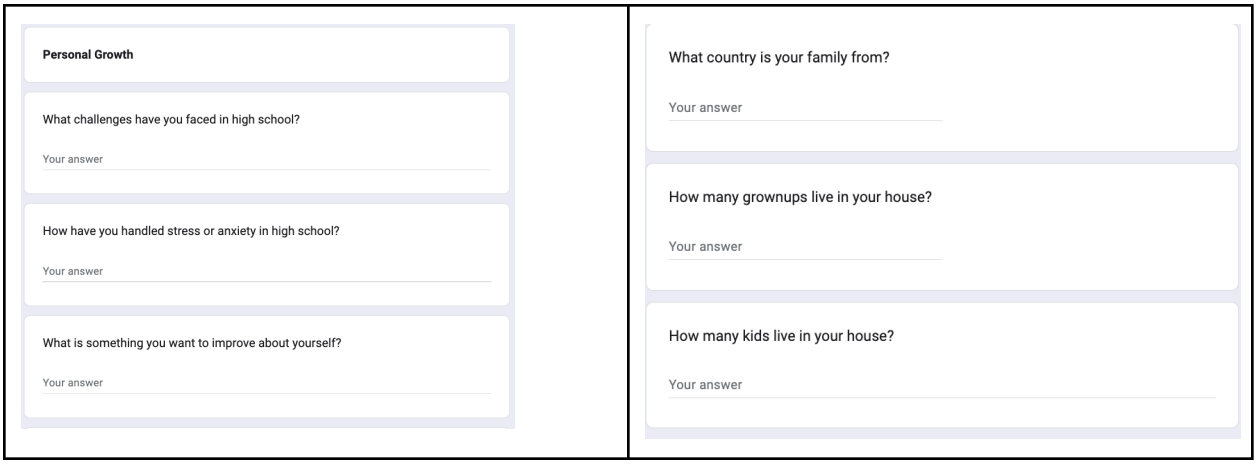
for one area, we can use that to better inform the algorithm about what really matters in forming these relationships.

Another assumption we make is that if a student has a favorite teacher, that relationship is successful. Although this is not a guarantee and the teacher could fail academically, we are comfortable making this assumption because our observations in real classrooms told us that students were more engaged with teachers they found enjoyable. Therefore, a student will learn better if they get along with their teacher.

We also included information about demographics in our quiz because we learned through Project Excite reports that students of color benefited from being tutored by someone successful who looked like them. This source of affirmation went a long way in motivating students to work hard. This is why the Research Quiz has the ability to convey if this is important for the given area. Another decision we made based on secondary research was our word choices. We used this guidance to choose words that our target age groups easily understood.

## Questionnaire

The questionnaire is actually the part that prospective students and tutors contribute data for. They fill out questionnaires that ask them about their identity, values, and hobbies. These questionnaires use language that is tailored to the age group they are targeting. For example, a questionnaire for a tutoring program for elementary schoolers would use more kid-friendly language than a program for teens or adults. Questionnaires meant for very young kids also include little breaks between chunks of questions. These breaks include verbal encouragement and little activities to boost engagement with the questionnaire.



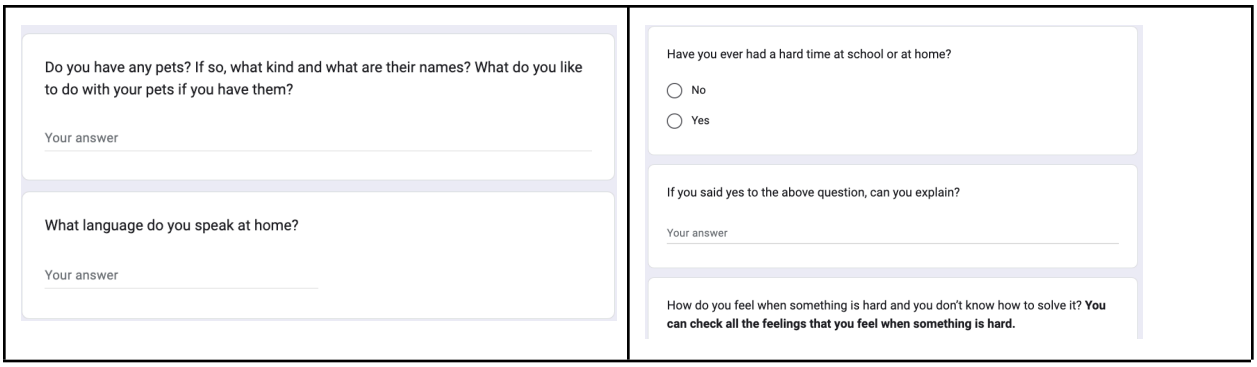



Fig. 1. Sample Mentee Questionnaire Questions.

## Rationale

In order to gather the information needed to match students and tutors, we needed some kind of questionnaire. We chose to make our questionnaires on Google Forms because they are easily distributable and present data in a manageable way. We wrote the questions such that we can learn as much as possible about a given student or tutor without wasting their time.

Despite this, the questionnaire is still lengthy and would require something to keep younger children engaged. Based on our observations in real Chicago classrooms, we noticed that kids lose focus when there is too much fun to be had—or not enough. Therefore, the small activities in the questionnaire are designed to strike a balance between fun and boring that maintains the young student's attention. Specifically, many of these activities are physical, allowing the kids to exert a lot of their pent up energy. We again used research about word choice to influence our decisions in writing the questionnaire.

## Algorithm

The algorithm takes in tutor/student data from the questionnaire and weight data from the research quiz and creates pairs. The first step in this process is creating a "match score" for every tutor and student pair. We do this by comparing their answers in the questionnaires and finding similarities between tutors and students. For example, take this student and tutor:

**Table I**
**Converting questionnaire questions and responses to algorithm metrics**

| Questionnaire question | Student answer | Tutor answer | **Result** |
|---|---|---|---|
| Would you rather sing and dance or play a sport? (weight 0.7) | Play a sport | Play a sport | Match! Match score increased by 0.7 |

| | | | |
|---|---|---|---|
| Do you like to spend time with a lot of people, just a few, or none? (weight 0.3) | A lot of people. | I like to be alone. | No match. Match score is not increased |

Once all the match scores are calculated in this way, we will have a matrix of match scores with each row representing a student and each column representing a tutor. For example, cell (2,3) in the matrix would hold the match score between student 2 and tutor 3.

We can then use this matrix to assign tutors to students. We will look at each student and find the tutor they have the highest match with to pair them up. If a tutor already has four students, we move on to the next best match. In small groups of students, this works fine, as most students will get their optimal tutor.

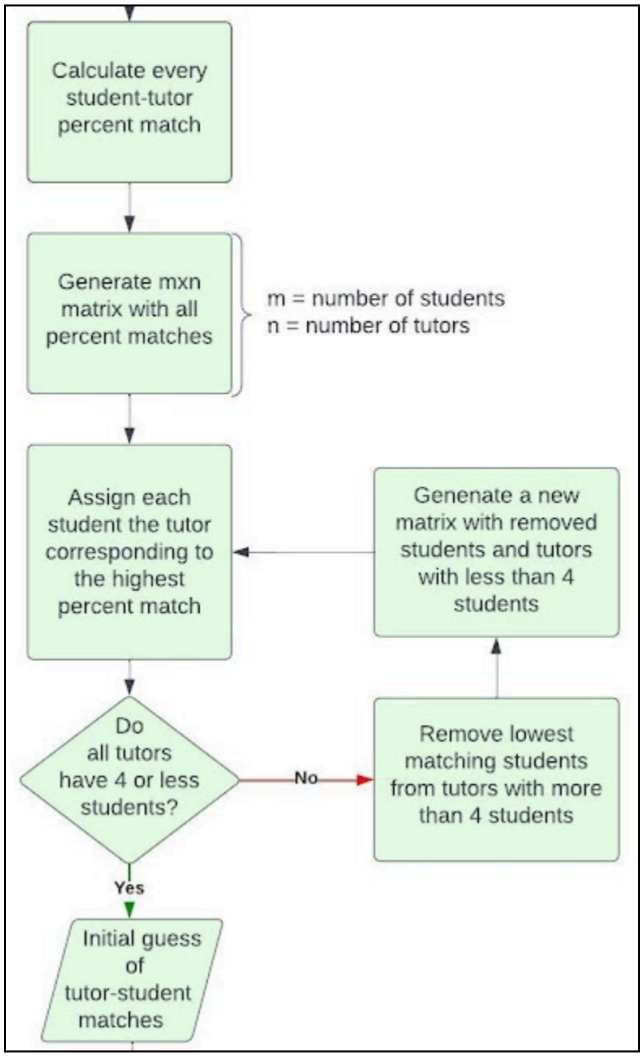



Fig. 2. Generating the initial guess.

However, we will begin to get suboptimal pairings when using this process on larger groups of students, as students near the top of the list will get better matches (if 10 students have their highest match score with tutor 5, how do we choose who gets that tutor?).
Our solution to this problem is to use a hill-climbing algorithm:

1. First, we generate an initial guess with the previous method.
2. Once we have the initial guess, we calculate the overall match score by adding all of the individual match scores together. Our goal is now to optimize this overall match score.
3. The hill climbing algorithm works by making a small change (ex: swapping two students) and seeing if that improves the overall match score.
4. If that works, we accept the change and try a new swap. If it doesn't work, we reject the change and try a new swap.
5. This process repeats indefinitely until we reach a desired overall match value called the "threshold."

The threshold value will be determined by trial and error when running the code, as some threshold values will be impossible or take an unreasonable amount of time to achieve. In the event that the threshold is impossible to meet, there is a failsafe that stops the code after about 15-18 minutes. Due to the nature of the code, the final matches produced after 15 minutes are likely the best matches possible.

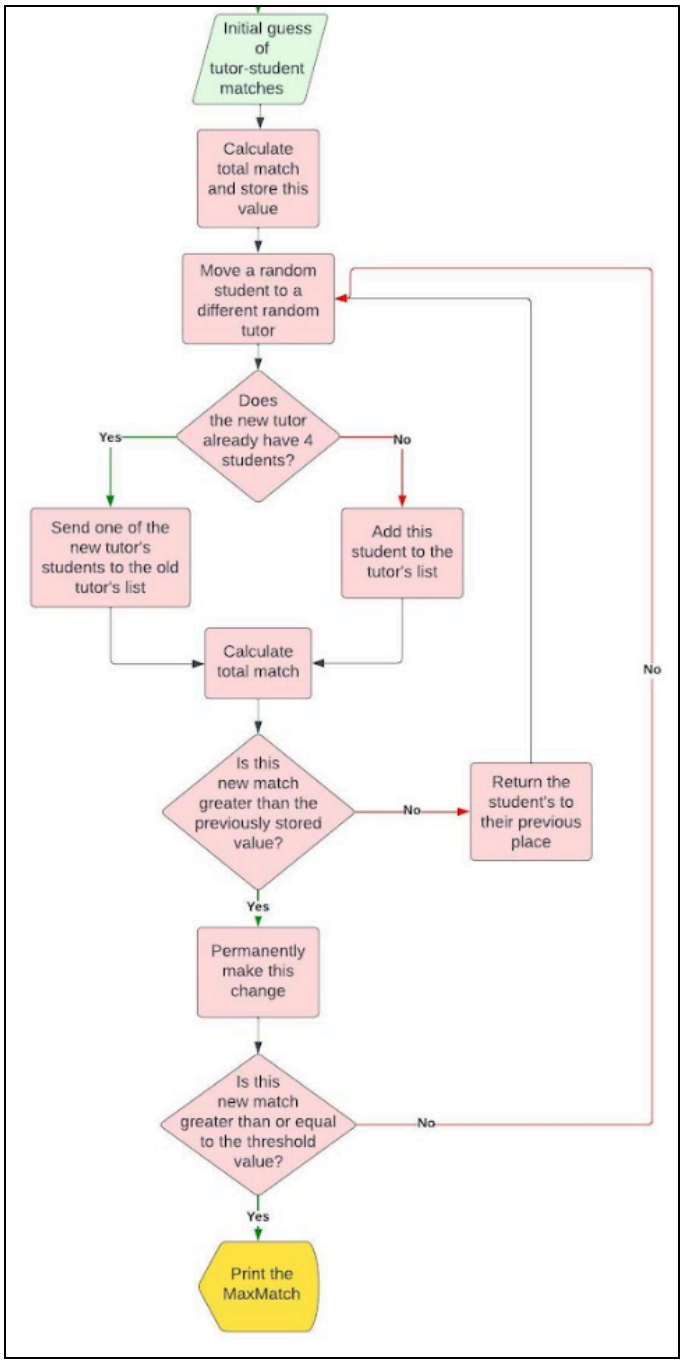



Fig. 3. Detailed view of hill-climbing algorithm.

**Rationale**

The choice to use an algorithm comes from the expectation that we will have a significant amount of data to sort and compute. Using a computer to help with the data will both remove bias and make the pairing process faster and more accurate. In terms of specific algorithm choices, we initially tried to use a direct pairing process (rather than iterating randomly in the hill-climbing algorithm). However, we quickly realized that this approach is either impossible or way beyond our skill level, so we decided to take a simpler approach. The first step of the

process (creating pairs sequentially based on the highest match score) works perfectly for small sample sizes and works very well for medium sample sizes, but could create unfair matches when dealing with large numbers of students (roughly 40+). Our arrival at a hill climbing algorithm was informed by secondary research on what kinds of algorithms are used for pairings.

Our decision to limit the maximum number of students per tutor to four was a product of an interview conducted with Jaime Sulzer, who was very familiar with Project Excite and other tutoring programs. Any more students than four would be too great an undertaking for a college-aged tutor.

We also chose to prioritize the highest overall match score on the basis of maximizing overall good. If we prioritized individual student matches, we would ultimately have to make choices about which students would get the best matches.

**Table II**
**Hypothetical student-tutor matrix**

| | Tutor 1 | Tutor 2 |
|---|---|---|
| Student 1 | 90 | 80 |
| Student 2 | 80 | 50 |

For example, if you had to assign the students from the above table such that each student is paired with one tutor on the basis of highest individual match, Student 1 would be matched with Tutor 1 and Student 2 would be matched with Tutor 2. However, in this situation Student 1 gets a really good match while Student 2 gets a subpar match with an overall match of 140. If we match on the basis of the highest overall match, Student 1 will be matched with Tutor 2 and Student 2 will be matched with Tutor 1. This produces two equal matches with a total match of 160. In a more realistic situation, the difference would be more subtle.

The hill-climbing method avoids specific ethical issues by trying to produce an equitable distribution of matches. We chose to put a cap on the amount of time the code can run because if a threshold is unobtainable, it would be hard for a program administrator to know unless they were familiar with the code. With the time limit, they are getting the best possible match without wasting their time.

# Future Development

## Next Steps

- Conduct further secondary research
- Further user and performance testing
- Maintenance issues
- Implementation plans
- Consideration of new features

## Conduct Further Secondary Research

It is imperative to conduct further secondary research to support the decisions behind the design concept. Some of the assumptions that influenced the design concept were due to limited access to information, so in future development, finding facts and data that support or counter the design concept will help in improving it altogether.

## Further User and Performance Testing

Before launching MaxMatch in Evanston, it is essential to conduct further user and performance testing. This would include administering the research quiz and generating the weights of the community. This would take multiple trial rounds to ensure the legitimacy of the research quiz in defining the weights of the questionnaires, but once this is complete, we would be able to distribute the questionnaires to a multitude of tutoring programs in Evanston. It would allow them to then provide us with feedback on the questionnaire, in terms of its logic and relevance to the process of matching a student and tutor. Then, once we would make our final revisions to our research quizzes and questionnaires, we would send them out once again to gather the data that would be used to test our algorithmic program; finding and then debugging any issues that may be embedded within it. Once all of this is completed, our next step would be working to officially implement MaxMatch in tutoring programs in Evanston.

## Maintenance Issues

As mentioned prior, for future development, we want to define further the process of translating research quiz answers into weights for the matching questionnaires. As of right now, the process is tricky and not firmly defined, due to limited user testing. So, in the future development of the program, we would conduct more research on tutoring programs that have experience in matching students and tutors, interviewing people on the systems they use and how we could refine our matching methods and algorithms.

## Implementation plans

Once the MaxMatch algorithm is crafted and refined to completion, the next step would be to work toward creating and implementing the program around it, for members and entities of the Evanston community to become a part of. This would include reaching out to schools,

universities, and other outside sponsors and organizations for support for this program, primarily in terms of funding. For the program itself, we would need to develop the recruitment process, hiring people to manage the various attributes of the program, such as:

- Administrators to manage the operations of the program
- Programmers to refine the algorithm
- Researchers and writers to improve the research quizzes and questionnaires
- Marketers to advertise the program to tutoring programs and families in the community
- Social workers to help with more extreme cases of mental and emotional support
- Students ranging from ages 18-22 years old volunteer to be tutors

Managing all these attributes will take diligent planning in the future development of this program, so it is essential that when conducting these next steps to be conscientious and meticulous in its implementation.

## Consideration of New Features

The entire purpose of the MaxMatch algorithm is to create compatible matches between an older mentor and a young mentee of color; thus, the next step following the development of this algorithm is to create a tutoring program specifically tailored to students of color. In addition to the MaxMatch program itself, it is imperative not to forget its main intention: to help close the achievement gap between students of color and their white peers. Thus, as a supplement to the MaxMatch, future development of this program would be creating a specific MaxMatch Tutoring Program; since right now, MaxMatch is just a tool that any and all tutoring programs can use to efficiently match students and tutors. So, in contrast, the MaxMatch Tutoring Program will be a unique organization tailored specifically to students of color. It would act as a safe space for students of color to grow, learn, and evolve together, maturing into individuals who yearn for learning and bettering themselves to become educated, worldly members of society. With this, every single resource of the tutoring program would go to helping students of color become on par with their white peers by the time they reach high school, giving them an equal opportunity in seeking post-secondary education.

# Conclusion

In conclusion, the creation of MaxMatch presents a promising solution to address the achievement gap between students of color and their white peers in Evanston. By leveraging a matching algorithm powered by research quizzes and tailored questionnaires, MaxMatch aims to efficiently pair students with tutors who can provide them with the necessary academic, social, and emotional support. This program fills the void left by the termination of Project Excite and offers a low-cost, accessible solution for tutoring programs in the area.

The underlying goal of MaxMatch is to ensure that all students, regardless of their gender, race, ethnicity, or other attributes, have equal opportunities to receive an exceptional education. By fostering suitable and compatible mentor-mentee pairings, MaxMatch aims to empower students of color, equipping them with the self-confidence and discipline needed to excel academically and pursue higher education.

To achieve long-term success, it will be crucial to gather feedback, monitor the program's effectiveness, and make necessary adjustments. Additionally, collaborative efforts from various stakeholders, including local schools, community organizations, educational institutions, and tutoring programs will be vital in ensuring the sustainability and growth of MaxMatch.

By implementing MaxMatch, we can strive towards a more equitable and inclusive educational system, where every student has the opportunity to thrive and reach their full potential. Through collective efforts, we can bridge the achievement gap and create a brighter future for all students in Evanston and beyond.

# References

[1] R. van Maarseveen, “The urban–rural education gap: Do cities indeed make us smarter?,” Journal of Economic Geography, vol. 21, no. 5, pp. 683–714, 2020.

[2] S. Assari, A. Mardani, M. Maleki, S. Boyce, and M. Bazargan, “Black-White Achievement Gap: Role of Race, School Urbanity, and Parental Education,” Pediatric Health, Medicine and Therapeutics, vol. Volume 12, pp. 1–11, Jan. 2021, doi: https://doi.org/10.2147/phmt.s238877.

[3] “Evanston Twp High School: Low Income Students,” EVANSTON TWP HIGH SCHOOL | Low Income Students, 2022. [Online]. Available: https://www.illinoisreportcard.com/school.aspx?source=studentcharacteristics&source2=lowincome&Schoolid=050162020170001. [Accessed: 05-Apr-2023].

[4] E. Garcia and E. Weiss, “Reducing and averting achievement gaps: Key findings from the report 'education inequalities at the school starting gate' and comprehensive strategies to mitigate early skills gaps,” Economic Policy Institute, 27-Sep-2017. [Online]. Available: https://www.epi.org/publication/reducing-and-averting-achievement-gaps/. [Accessed: 05-Apr-2023].

[5] “Closing the achievement gap . the program,” PBS, 2004. [Online]. Available: https://www.pbs.org/closingtheachievementgap/program.html. [Accessed: 05-Apr-2023].

[6] “Impact - educate. Radiate. elevate.,” *Educate Radiate Elevate*. [Online]. Available: https://www.educateradiateelevate.org/impact/. [Accessed: 05-Apr-2023].

[7] D. Ludvik, “Four promising factors to close opportunity gaps among children of color,” *Early Learning Network*, 07-Dec-2020. [Online]. Available: https://earlylearningnetwork.unl.edu/2020/06/29/four-promising-factors-to-close-opportunity-gaps-among-children-of-color/. [Accessed: 05-Apr-2023].

# Appendices

## Appendix A: Project Definition

**Project Definition** V4, May 26, 2023

**Project Name:** "Max Match"
**Client:** Mark Vondracek
**Team Members:** Danny Kim, Tim Bachman, Ryan Payne, Victoria Laguerre

**Mission Statement:** To develop a matching algorithm to be used by tutoring programs in Evanston that pairs tutors with students of color to help close the achievement gap at Evanston Township High School, by mentors providing academic and social support to mentees.

**Project Deliverables:**

- Final Report
- Final Presentation

**Constraints:**

- **Time Constraint:** All deliverables must be completed and submitted by June 3, 2023. This places a high priority on effective time management and efficient execution to ensure timely project completion.
- **Budget Constraint:** The project has a limited budget of $100. This financial restriction necessitates careful budget planning and resource allocation to maximize the available funds and deliver high-quality outcomes within the allocated budget (most likely not used).
- **Interviewing Younger Students:** Younger students can be challenging due to their natural characteristics. Their limited attention spans and potential difficulty expressing themselves may require particular strategies to engage them effectively and gather valuable insights.
- **Limited Pool of Tutors:** With fewer tutors available, it becomes crucial to optimizing the matching criteria to ensure the best possible pairings within the given options. However, due to our limit of 4 students per tutor, not all students may be matched with tutors, necessitating careful consideration in the pairing process to maximize the effectiveness and satisfaction of the matched pairs.
- **Inability to Visit Elementary Schools:** The inability to visit elementary schools for user testing and observation poses a challenge in gathering firsthand insights from the target audience.
- **Busy Schedule of School Teachers:** School teachers may have limited availability due to their busiest schedule this time of the year. It might be challenging to coordinate and

conduct informational interviews with them. Alternative approaches or flexibility in scheduling should be considered to accommodate their availability and gather the necessary information.

- **Data Privacy Concerns:** Due to data privacy concerns, distributing questionnaires and forms to the target audience is not feasible. Instead, the project will rely on distributing the surveys among friends to gather the required data. This approach requires careful consideration to ensure the friends' characteristics align with the target audience and provide representative insights.

**Users and Stakeholders:**

**Users:**

- Tutoring Programs
    - Students in the tutoring program
        - Pre-high school Evanston Students
    - Tutors
        - Northwestern Students/ETHS students

**Stakeholders:**

- Teachers
    - Teachers of the Evanston students that are involved in the program
- Parents
    - Parents of the Evanston students that are involved in the program

**User Profile**

- **Student**
    - Meet George, a vibrant and curious third-grade student who is full of personality and potential. Despite facing some challenges in focusing during class, George is a very funny and engaging student who loves to chat with his peers. Even more impressive, George has developed a passion for robotics and engineering, despite not having the opportunity to build anything due to his family circumstances. George is a student of color, living with his hardworking mother who is a nurse. With his natural wit, creativity, and burgeoning interests, George has the potential to accomplish great things and make a positive impact in his community.
- **Tutor**
    - Meet Mellie, a caring and passionate individual who is committed to making a positive impact in her community, particularly in addressing educational inequality. When she learned about a new program from the Segal design center involving tutoring local elementary school students, Mellie is eager to join and use her skills to help struggling students while gaining experience in her profession.

**User Scenario**

- George's teachers have noticed that he could benefit from additional academic support, prompting his mother to look into tutoring programs offered by Northwestern University. After discussing the opportunity with George, they both decide that it could be a great chance for him to receive the extra help he needs while working with older students, which he is excited about. To enroll in the program, they fill out a simple form detailing George's interests, academic strengths and weaknesses, and other relevant information that could help match him with a tutor who can best support his needs. After a few weeks, George receives an email informing him that he has been matched with a tutor. He and his mother are both thrilled to learn that his tutor is someone who shares his love for robotics and engineering, and has experience tutoring other students with similar interests. In their first session, George and his tutor hit it off immediately, bonding over their shared passion for STEM subjects and working collaboratively to address any academic challenges that George may be facing. Over time, George's tutor not only helps him with his studies but also becomes a role model and mentor, inspiring George to pursue his interests and work towards his goals. With the support of his tutor and his mother, George gains the confidence and skills he needs to thrive academically and pursue his dreams.

- Mellie, an eager and passionate student, learns about a new program from the Segal design center involving tutoring local elementary school students in her SESP class. Despite never having tutored in high school, Mellie writes down the email the professor provides and decides to reach out to them. After submitting her application at the last minute, Mellie is paired with 3 groups of 4 students, each needing help on a different subject. Overwhelmed with the prospect of creating three separate curriculums, Mellie reaches out to the program for help and is reassured that the program is looking for mentors and role models, rather than professional tutors. Although nervous at her first tutoring session, Mellie feels like she has done a decent job and her students are excited for her to come back the following week. Over time, Mellie becomes a mentor with her tutees and friends with her fellow tutors, feeling fulfilled by the community the program has fostered and gaining the confidence that teaching is her calling.

**Table III**
**Needs/Requirements Matrix**

| Requirement or Need | Metric | Target Specification |
|---|---|---|
| Longevity of the partnership between mentor and mentee | Mutual mentor and mentee engagement<br>- Meet at least once a week for a couple hours a day<br>- Engage in different activities together each session<br>- Encourage a supportive relationship between the mentor and mentee even after their time in the program ends | Greater than 90% mutual attendance to tutoring sessions, minimal cancellations. Greater than 80% of the student-tutor pairings staying semi-in-touch even after their time in the program ends |
| Pairs students with tutors who prioritize social-emotional development and utilize positive reinforcement techniques to create an engaging and enjoyable learning experience. | Student enjoyment<br>- Surveys and Questionnaires<br>- Self-Reports<br>- Attendance and Participation<br>- Interest and Enthuasiam: assessed through classroom observations or teacher assesments | Greater than 80% positive feedback on retrospective surveys. Greater than 90% attendance. |
| Provide an environment that challenges students to excel and grow | Student academic improvement<br>- GPA<br>- Standardized Test Scores<br>- Course Completion and Advancement<br>- Attendance and Punctuality<br>- Teacher Evaluations | Student is improving faster than they were before being matched with a tutor via our program |
| Provides tutors with information about students | Tutor confidence before the first session | Greater than 80% positive feedback from tutors about their preparedness |

| | | |
|---|---|---|
| Accounts for unique students | Success rate of needs 1 and 2 | Less than 5% deviation from the average performance increase for students with disadvantages |
| Simplicity of Surveys | Average time to complete survey | 10-15 minutes |
| Ability to reassign tutors and students | Ease of manual match modification in the algorithm | Matches can be updated in the algorithm in less than 5 minutes |

# Appendix B: Project Partner Interview

## Introduction and Methodology

On Wednesday, April 12, 2023, at 3:45 pm, my team member Ryan Payne and I had our initial interview with our project partner, Dr. Mark Vondracek, at Evanston Township High School. Mr. Vondracek is a Physics teacher at Evanston Township High School and the creator of Project Excite. The purpose of the meeting was to interview Mr. Vondracek to learn more about Project Excite and gain a better understanding of how it worked to combat the educational achievement gaps in Evanston and Chicagoland, as well as the successes and fallouts of the program.

## Problem Statement

The educational achievement gap between students of color and white students has been growing for decades. According to Mr. Vondracek, due to socioeconomic status and the lack of resources for students and families in more impoverished communities, it was only inevitable that the more affluent students were seeing more academic success, especially in predominantly white communities. For instance, as stated by Mr. Vondracek, achievement gaps expand even more over the summer as wealthy people have camps and other summer programs to keep their children engaged over the summer; and this is something that, due to socioeconomic factors, those other families can't do anything about. Thus, Project Excite set out with the mission to close that gap, and according to substantial data reports, it was successful in doing so when the program was running. However, when Northwestern University ceased its 80% funding contribution, the program was forced to shut down. Thus, my team's job is to develop an educational program that combats the achievement gap as Project Excite once did and prevents any pitfalls that might have led to the program's end.

## Background

Project Excite began in 1998, but it took one and a half years to get the pilot program started; its first cohort met in 2000. Following this, Mr. Vondracek and his other colleagues whom he worked with to develop the program had many talks with District 202 – which consists of Evanston Township High School - and the Northwestern Center for Talent Development(CTD) to gain their support for the program, which they provided promptly. However, it took a few months to get District 65, a school district in Evanston, on board with the program. Once that was eventually accomplished, Project Excite had its key supporters who funded the program to make it free for the families of children.

## Users

- Students of color, primarily those of the elementary and middle school levels, before entering high school
- Poorer families that are less likely to have educational resources

- Parents who would be placing their children into the supplementary educational program
- Teachers who are willing to teach this supplementary educational program
- School and district administrators that have to approve the implementation of the program

## Program Details

- Launched in 2000
- Applied to schools in District 202 and District 65 in Evanston, Illinois
- Applicable for students between grades 3-8, before entering high school
- According to Mr. Vondracek, it was optimal for the program to begin for students at a young age and for it to be designed for the long term.
- Connecting with the parents of these students is essential
- Students, especially those at the elementary level, went to the high school during after-school hours to receive supplementary learning in math and reading.
- The main mission of the program was to close the achievement gap between students of color and their white counterparts by getting students excited about school and expanding their sense of possibility. It was about changing people's expectations about what they can do as learners. The goal was to build up self-confidence and a sense of belonging, showing these younger students of color that they are more than capable of being at the same academic standings as their white peers. To accomplish this, the following was enacted–
    - The main goal was to
        - *"It was on the social/emotional side."*
    - Academic content was a lower priority.
        - *"The content will come with time."*

## Specifics

- At the program's start, every session focused on basic skills on a different topic/subject to excite the students.
- Teachers were mostly hands-off, and current high schoolers taught the kids.
- These older student role models were integral as they made the elementary students feel more comfortable engaging with students they could relate to.
- Fourth-grade through eighth-grade students had a lot of focus on the Center for Talent and Development(CTD). During the school year, Excite students could choose classes during the Saturday Enrichment Program at CTD. This made them more academically on par with their white/Asian peers.
- Third graders had 10 sessions for the whole school year, but fourth to eighth graders only did two sessions of the Saturday Enrichment Program entirely through CTD.
- Fourth to eighth-grade students also enrolled in CTD summer programs, staying in dorms with other children from all over the country.

- Excite students who began the program in third grade typically stayed with it until high school when the program ended. Families and students committed to the program from the very beginning, and this is what allowed the program to see so much success in lessening that achievement gap – essentially, the program experienced a zero percent dropout rate, with the exception of families that moved out of the district.

## Financials and Funding

- Northwestern University contributed 80% of the funding for the program
- District 202 and District 65 contributed 20% of the funding for the program
- Smaller grants from private organizations, such as Coca-Cola
- The biggest expense that needed to be funded was tuition for CTD Classes, being $3,000 to $4,000 per student.

## Testing

The main testing process to quantify the success of the program was the Naglieri Nonverbal Ability Test, which is an exam used for qualifying K-12 students for gifted and talented programs, but according to Mr. Vondracek, the goal was never to compare Excite students with “gifted” students. The goal was to eliminate bias, and the test results weren't something they were interested in. Project Excite wasn't supposed to be a "gifted" program; they were choosing kids who were average or below average to help them become on par academically with their peers.

The Naglieri exam was focused on pattern recognition; it was being used to find kids who enjoyed the academic challenge and wanted to learn. That is what, as Mr. Vondracek said, “Project Excite was all about.”

## User Opinions

The following list describes the opinions on Project Excite from Excite kids, their parents, and the teachers involved in the program, as explained by Mr. Vondracek.

- Abundant amounts of support from teachers and the parents of children involved in Excite
- Excite students enjoyed every part of the program since these students truly wanted to learn and attain the most out of their education.
- Students especially loved the Bridge Program of Excite, which was a program during the summer before eighth graders entered high school. The Bridge Program was designed to help them with the transition.
- The program had a substantial effect on diversity in upper-level classes at the high school, so it was frustrating for Mr. Vondracek to see how the race disparity in upper-level classes increased once again after Excite ended.

## Outcome and Fallout

While the program did see significant success in lessening the achievement gap between students of color and white students, several issues escalated towards the end of the program which led to its ultimate demise.

- There was significant demand for the program, but there was no efficient way to bring more sponsors into the project.
- Northwestern ceased funding because of the idea that most programs are funded for about 15-20 years, so the university felt compelled to make a new decision about how to allocate funds, a decision that did not involve funding Project Excite.
- A former dean of Evanston Township High School was against the project. The dean thought the children in Project Excite should be committing to higher-level schools, such as Ivies and Northwestern-level institutions, instead of the "lower" tier state schools to which they committed.
- Eventually, CTD started to support a college preparatory program instead of Project Excite, leading to the program's final demise.

## Future Program Requirements

All this information considered, as outlined by Mr. Vondracek, we are to create a new program that sets out to accomplish the mission of Project Excite, but this program will not be Project Excite. We will only reference Project Excite, as well as all of our other secondary research, to create a project that isn't as vulnerable to the issues and constraints that Excite faced and will simultaneously excel in Excite's success rates of closing the achievement gap. To do this, there is a laundry list of requirements, some being:

- The program has to begin for students of color at a young age, meaning early elementary until the end of middle school, before they enter high school.
- Recommended that students of color join the program as early as possible as it should be a long-term experience
- Substantial funding is required from school districts, universities, private organizations and donors, and/or state and federal funding.
- Approval by district administration - superintendent
- Final approval vote by the school board for definite implementation

**Important notes:**

- Project Excite is not a gifted program that helps students who are already doing well.
- It is a program of social and emotional learning working to build up the self-confidence of students who want to learn.
- It is not necessarily focused on achievement, such as prestigious college admission, as the phrase "achievement gap" might suggest. Rather it is focused on providing students of color with the same opportunities as their white peers so they can be on par with them, and thus, have equal chances of succeeding in all their academic and professional endeavors.

## Constraints

- Long-term funding
    - Ensuring that there isn't only one organization that is contributing so much of the funding that without it the program would cease
    - Ensuring that these organizations are contractually committed to this sort of educational program for the long-term, such as over 20 years.
- Socioeconomic factors
    - It is impossible to resolve all of the socioeconomic constraints that limit some families' accessibility to educational resources, which consequently contributes to the achievement gap.
- Politics
    - For example, the superintendent for District 65 was difficult to work with when Project Excite was first being developed, which is why it took so long for the program to be implemented.
    - The current superintendent of District 65 is leaving after the 2022-2023 school year, which will call for a lot of turnovers in their administration and temporary stability; so proposing and implementing an entirely new program will be challenging.

## Follow-up Questions

- How do we address the various issues of funding and the constraints that it has on developing this program?
- While we can't solve socioeconomic issues, how do we get around them to truly make this program accessible to all impoverished families?
- How do we get schools and districts to easily be on board and willing to implement a program like this again after it ceased in the past?
- How do we demonstrate to large institutions, both public and private, that this type of program is worth funding?
- How do we create a program where we don't need one large sponsor, like Northwestern, to fund it to the point where it is the "end all be all" of the program?
    - Is there a way to do this internally, rather than involving an outside community like CTD?
    - How can we emulate CTD?
- Could we build stuff into summer school programs?
- Would teachers at ETHS be willing and able to design their own supplementary classes as Mr. Vondracek suggested?

## Next Steps

- Interview Mr. Vondracek one or two more times
- Interview teachers from other schools in Evanston and the surrounding area to gather more insight into their educational systems
- Observe classrooms of multiple schools to gather knowledge on their learning environments and student interaction with the material and each other
- Interview students, especially past students of Project Excite, and gather intel on the best learning environments for them
- Interview Northwestern and CTD administrators who were involved with Project Excited about their thoughts on the program and its cease in funding
- Conduct more secondary research on the logistics of a program like Project Excite, such as:
    - What, specifically, worked and what didn't?
    - Success rates in terms of closing the achievement gap
    - What factors led to the program's end?

## Conclusion

In conclusion, considering all this information gathered from the initial primary interview, it is safe to conclude that there is much more research to be done to determine how to efficiently approach this problem, and create a new program that addresses both the main mission and the issues of the past that led to the downfall of Project Excite. The primary interview helped in understanding the logistics of developing and implementing a program like this, and the data on the success rates of the program proves that a program like this can be successful. There are simply more underlying factors that need to be considered, addressed, and combatted for this project to be a more permanent one. One that can truly lessen and, hopefully, close the achievement and opportunity gaps.

# Appendix C: Ethical Considerations

## Introduction

Our team was tasked with developing a strategy to help students of color who are falling behind in school catch up to their peers. We identified that the best way for a project of this scale to reduce this issue is to develop a more robust system to pair tutors and students in already existing tutoring programs. As this project deals with complex socioeconomic issues, we have created this appendix to detail our ethical considerations while designing our solution. Drawing from the Design Thinking and Communications Textbook and NSPE Code of Ethics, our approach is split into five sections: development, manufacturing, user impact, social impact, and end of life.

## Development

In development, we will stay focused on creating an overall improved experience for our users.

1. We will define example end users to focus our solutions
2. We will test the product with users and get their opinion on how our product compares to alternatives
3. We will integrate user feedback into our design to make the product as easy to use as possible

## Manufacturing

Although our product will not have much of a physical component, we will still make sure the implementation of our process is consistent with our ethical considerations.

1. We will create the process such that it can be used students of color, as to not exclude anyone from the process
2. We will seek to use data collection methods that are secure and transparent so we can ensure that our users data is protected

## User Impact

Our product should be catered to our users' needs.

1. The product will be focused on improving matches between tutors and students, rather than collecting data on how certain types of people work together
2. Users' data will not be shared with other organizations unless approved by the user
3. The matching process should not take an excessive amount of time
4. The matching process should have as little financial impact as possible to save school funds for other projects

5. We will promote the adaptability of the program to our users to make sure they don't feel pressured to stick to our specifications

## Social Impact

We will seek to bring together the local community through the tutoring and pairing process.

1. We will encourage tutors to connect with their students and fellow tutors to create a sense of community within the program
2. We hope that future tutoring programs will bring the community together by promoting more interaction between students of different ages

## End of Life

This matching system is designed to be iterated on to suit the needs of future tutoring programs.

1. Documentation on our process will be clear and will highlight places where other tutoring programs could change things according to their needs
2. After implementation, we will work closely with users and note ways in which they modified the program to suit their needs
3. Our system will be made such that it can be repeated year after year to continuously help pair students with tutors

## Conclusion

As we are creating and implementing our product, we will refer back to these considerations to make sure our product creates an overall positive impact on our users.

# Appendix D: User Observation

## Introduction

At this stage in the project we had a very limited idea of where we wanted our efforts to be directed. Therefore, this observation was geared to getting a good grasp on the difficulties and strategies of modern teaching in the Chicago area. In order to learn more about this, we traveled to the Dever Elementary School in Chicago on April 20, 2023 from 12:30 pm to 3 pm. During this time we observed four different classes from third to eighth grade in both math and ELA. Since we intended to gather as much information as possible, we took copious notes, trying to record a maximum amount of detail. We also paid extra attention to the interactions between students of different ethnicities and how students of color especially responded to the learning environment.

## Results

## Paying Attention

Across the board, many students struggled to pay attention, but this manifested in a few forms. Some kids would get distracted by their friends if they were left alone in a group activity, like in Ms. Heyward's math class. This problem seemed to exist for the first 10-15 minutes of the activity but went away as the teacher approached each group to assist or just to coax them into working harder.

Other kids seemed to just be disinterested and struggled to pay attention out of boredom. This problem arose visibly in Ms. Sherinfki's ELA class where kids seemed to be disinterested. It was also noted that this environment was stricter than the other classrooms. Students were placed in assigned seats and the teacher had a thoroughly defined lesson plan. The problem doesn't seem to be significantly resolved by the end of the class.

Also, the students of one classroom started the class in complete disorder. This was immediately resolved when the teacher, Ms. Leyderman, called for their attention. The class began to pay attention.

## Students of Color

The demographics of this school seemed considerably diverse, roughly 50% of students, based on observation, were students of color. One of the classes in particular, Ms. Guzman's, had a majority of students of color. We noted that despite differences in race, kids seemed to work together. There was no friction noted among groups of students.

## Teacher Approach

Teachers demonstrated a variety of strategies with varying degrees of success. In Ms. Heyward's class (Third Grade Math), kids were instructed on how to complete the planned activity and then they go off into groups to complete their task. As mentioned, focus takes a moment to kick in. Once students are focused, they use manipulatives to complete the activity. Kids seemed to enjoy the activity evidenced by getting a little rowdy at certain points. However, due to the teacher's guidance, they are brought back and finish the activity.

In Ms. Guzman's class (Eighth Grade), the kids and the teacher engaged together in banter as if they were just regular friends. On the day we observed, she presented a Polish film to her students. She also discussed current events with the students which she says she does daily. She likes to give the students autonomy to drive their own education. However, it seems this allows the few students who do not have this drive to fall behind; some students simply sit in the back of the class with their heads down.

In Ms. Sherinfki's class (Eighth Grade ELA), the teacher is more strict than her coworkers. She began by asking her students questions about concepts and then calling on specific students to answer. After this, students were placed in assigned groups and began an activity. There was a small amount of chatter among the students and a mixed amount of engagement per group.

In Ms. Leyderman's class (Sixth Grade ELA), kids were very excited and got along very well with the teacher. She also runs a more autonomous class. Students were assigned an activity and then were allowed to do something else once it is completed.

## Analysis

This observation most clearly told us the importance of the moderation of friendliness, moderation of freedom and group work. In terms of friendliness with students, teachers being too cold led students to be disengaged, while being their friend led the students to be too excited and struggle to engage in activities. Allowing students to work on their own seems to give them the confidence to tackle their own education, but leaving them completely unattended prompts the students to get distracted. Therefore, checking in with students early seems to greatly increase their performance during that activity. Group work seems to be a commonly used strategy in education and it is easy to see why. When students collaborate, any moment one student gets stuck, another is able to help them overcome that. This seems to mean that encouraging students to work with others and fostering that teamwork is essential to closing the achievement gap.

## Conclusion

In developing our design we must pursue something that effectively employs moderation and attempts to utilize the benefits of cooperation/teamwork. These lessons are useful despite the

limitations of our observation. Namely, these four classes cannot possibly represent the entirety of Chicago and Evanston schools. Also, we did not observe for very long. Despite this, we will apply these lessons to our design in the future.

# Appendix E: User Testing

## Introduction

This user testing aimed to gather valuable insights and enhance our understanding of the responses from our target audience. We also aimed to explore the preferences of both the kids (mentees) and mentors. Specifically, we were concerned with identifying key patterns of shared interests. The research was conducted over a two-week period, specifically during the last two weeks of May. Due to logistical constraints, the questionnaires and research quizzes were distributed within the Evanston area. The testing process involved sending out the research quizzes and questionnaires to our acquaintances and administering them manually at Evanston Township High School.

## Methodology

Due to data and privacy concerns, we faced limitations in directly distributing our questionnaires and quizzes to elementary and high schools, which comprised our target audience. However, we developed two alternative approaches to address this challenge.

1. In collaboration with Evanston Township High School, certain teachers volunteered to create their own questionnaires, mirroring the content of our original questionnaires. These questionnaires were then administered to their high school classrooms, and we obtained the results. The questionnaires were printed out and filled out by hand by the students.
2. We were permitted to send our questionnaires to individuals within our network of acquaintances. These participants completed the questionnaires online via Google Forms at their convenience. Although the sample size was limited, we still acquired valuable insights through this approach.

## Test Purpose and Detail

The questionnaires were created using Google Forms, which provides convenient visualization options for result analysis, allowing for clear data presentation through pie charts, bar graphs, and organized tables.

1. The mentee questionnaire aimed to gather insights about the child's preferences, interests, and personal characteristics. It included a range questions to assess their likes and dislikes, the reasons behind their preferences, and to understand their individuality better. The questionnaires were thoughtfully crafted using age-appropriate language to cater to younger children and included engaging and enjoyable breaks and activities to enhance their participation. The design took into account the unique needs and interests of younger kids, ensuring a more enjoyable and interactive experience for them.

2. The mentor questionnaire comprised different questions to provide us with a deeper understanding of the mentors. It explored their interests, preferences, and habits, allowing us to gain valuable insights into their personalities and mannerisms.

## Results

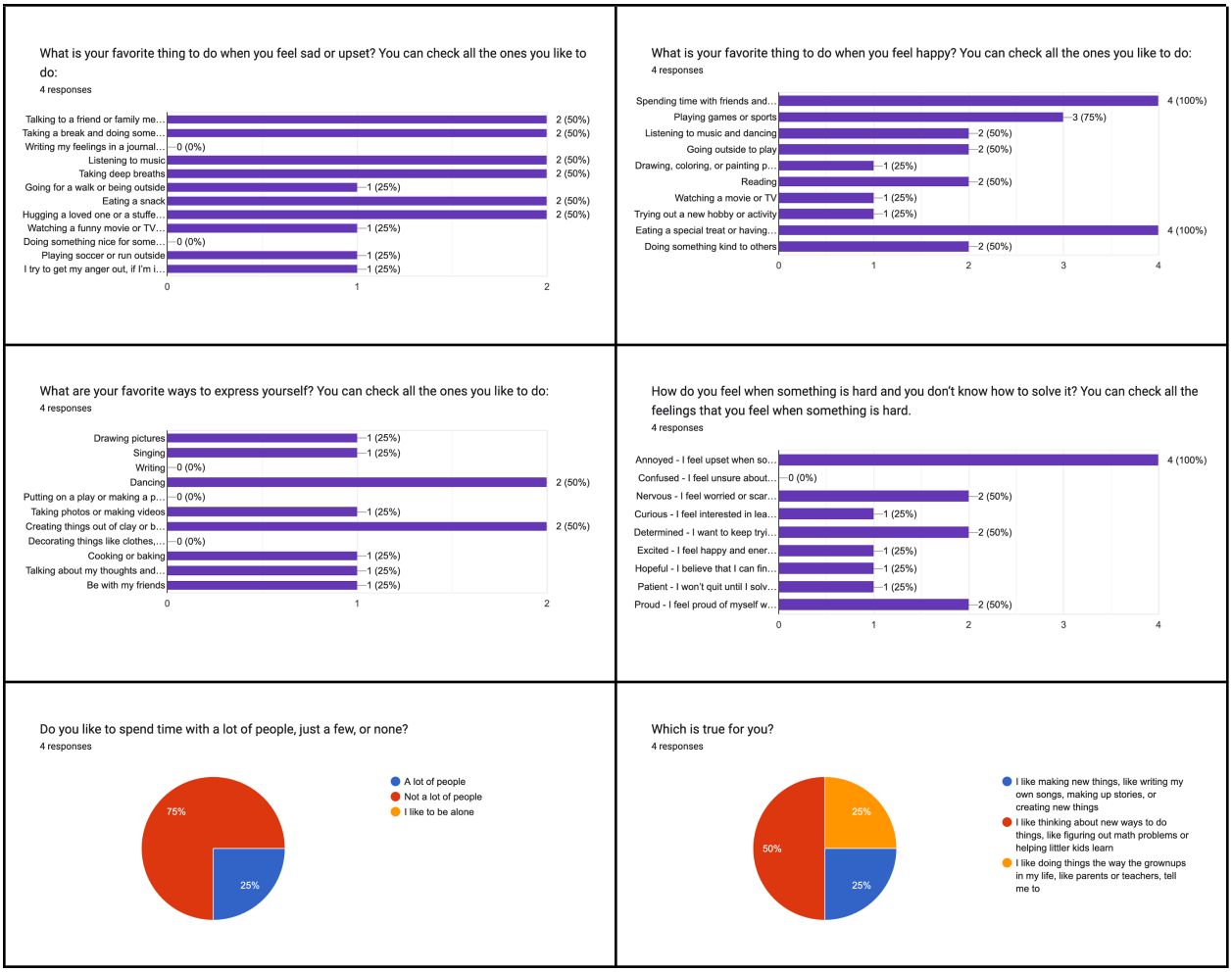



Fig. 4. Sample Responses from Mentee Questionnaire.

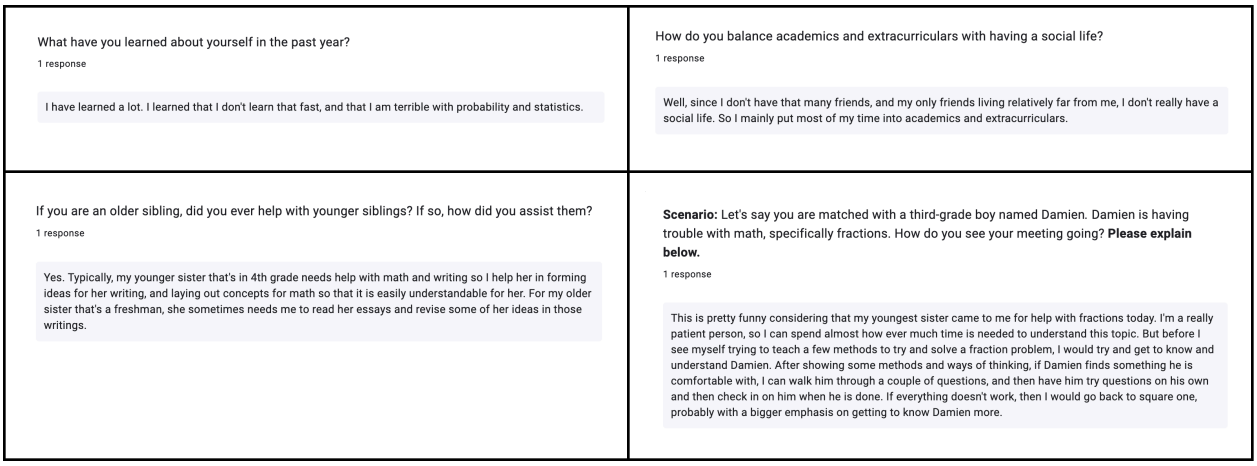



Fig. 5. Sample Responses from Mentor Questionnaire.

## Analysis of Results

From our results, our primary objective was to identify patterns among students from Evanston and to see and extract valuable insights to inform the weights of our MaxMatch algorithm. We discovered that mentors and mentees, despite their individual differences, frequently share qualities and have an appreciation for similar values. This finding strongly supports our understanding that the optimal tutor-student match can be quantified by comprehending both parties' shared interests and preferences.

## Limitations

It is essential to acknowledge certain limitations in our study.

1. One limitation is the relatively small sample size, primarily consisting of participants from our network of acquaintances. This restricted sample may not fully capture the diversity and range of perspectives of the larger target audience. Consequently, the generalizability of our findings to a broader population may be limited.
2. Additionally, due to the constraints imposed by data and privacy concerns, we could not observe certain aspects virtually or directly engage with elementary and high schools. This limitation may have prevented us from fully understanding the mentor-mentee dynamics and potential differences that could arise in a school setting.

# Appendix F: Instructions for Construction

Consult the following to implement the MaxMatch program.

## Algorithm Implementation:

1. If you don't have MATLAB, please install the latest version from the official MathWorks website: www.mathworks.com.
    a. MATLAB is a subscription-based software.
        i. Academic licenses are $275 per year.
2. Once MATLAB is installed, import the MaxMatch script into your MATLAB environment.
3. The program takes two inputs: a matrix of calculated scores and a threshold indicating the desired level of match quality.

## Variable Setup:

1. Set up a matrix of calculated scores:
    a. Prepare a matrix representing the calculated scores for each tutor-student pair.
    b. Ensure that each row corresponds to a student and each column corresponds to a tutor, with the calculated scores filled in the respective cells.

## Function Usage:

1. With the function imported and variables all set up, call the MaxMatch function and provide the following inputs:
    a. The matrix of calculated scores: Pass the variable representing the matrix of scores as an input to the function.
    b. Threshold value: Determine the threshold based on trial and error, if the code runs quickly based on your selected threshold, you can increase the threshold until the code takes 15 minute or more to run (a good starting threshold is 60*(number of students))

## Threshold Setting:

1. When specifying the threshold value, ensure it is a percentage ranging from 1% to 100%. This threshold determines the minimum level of match quality required for a successful pairing.
    a. Occasionally, it may not be possible to achieve the specified threshold. In such instances, the algorithm will automatically set the threshold to the highest percentage that can be attained.

Following these instructions, you can adjust the MaxMatch program to suit your specific needs, implement the scoring calculation, and set the threshold value accordingly.

# Appendix G: Instructions for Use

Consult the following for implementing the MaxMatch program.

## Research Quiz

1. Give the research quiz to a significant sample size (subjective, minimum 30 participants) in the desired age range.
2. Require participants to complete the full quiz
3. Convert each response into a numerical value (numbers for each hobby/value are defined by the administrator; it does not matter which are assigned to what value, as long as it is consistent). For example, liking music is a 3, playing a sport is 4 and watching movies is a 5)
4. Calculate the weights for each hobby/value by using the below formula

$$weight = c * \frac{number\ of\ times\ hobby/value\ is\ listed}{total\ number\ of\ responses}$$

Where c is a constant defined by the administrator

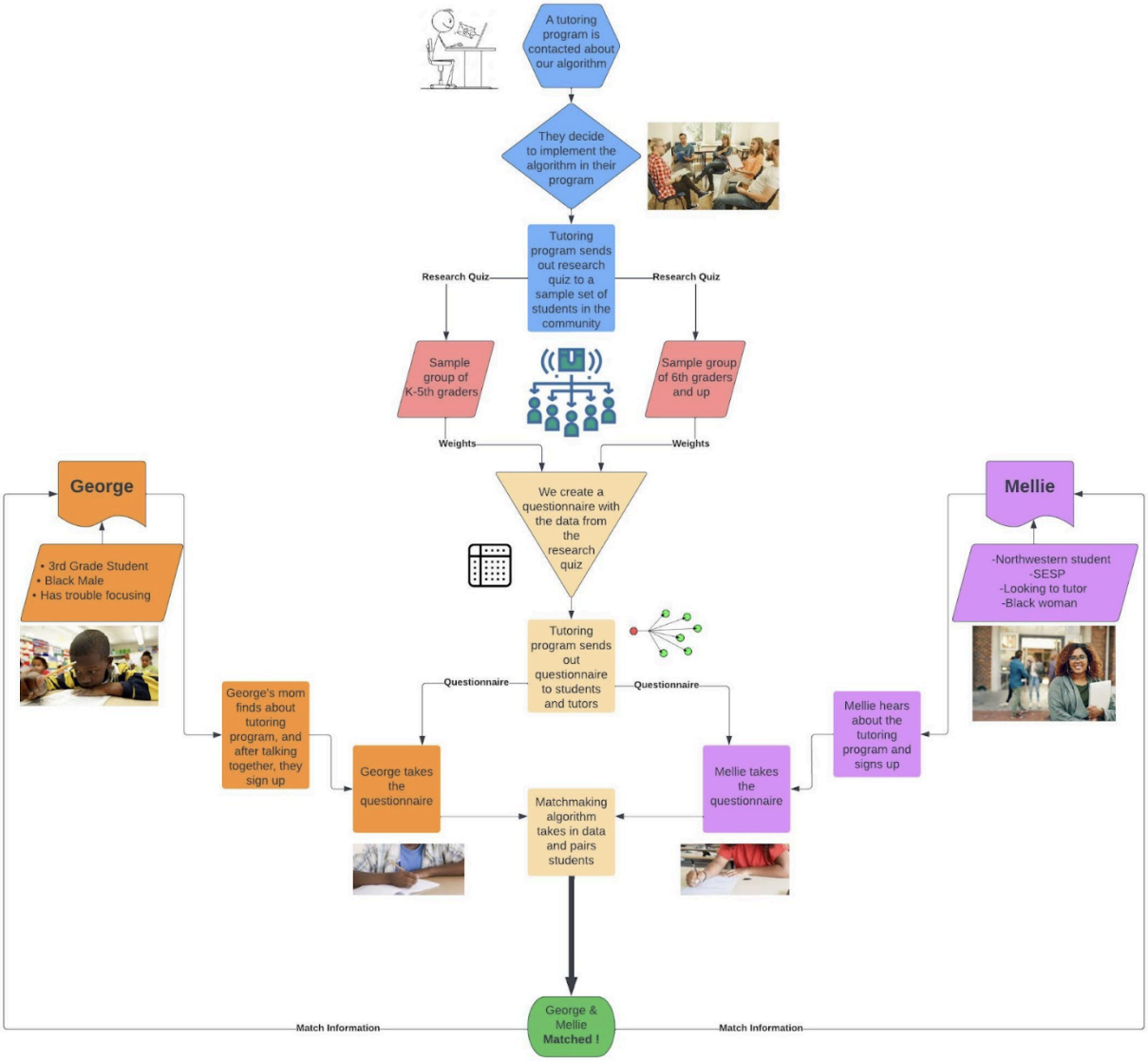
## Questionnaire

1. Give links to the appropriate questionnaire to all interested tutors and students
    a. 3rd-7th Grade receive the Kid questionnaire,
    b. 8th-12th grade receive Young Adult questionnaire (8th-12th is also applicable to adults and college students)
2. Require participants to complete the full questionnaire
3. Convert responses into numerical values (consistent with values defined in Research Quiz Step 3)

## Algorithm

1. Input hobby/value numbers for all students and tutors
    a. When run, the code will first ask the number of students and tutors
    b. Then it will ask one by one for the vectors containing the values for each student and tutor
    c. The vector's length will be determined by the number of categories included in the questionnaire
    d. The value of each element will indicate the response given by that particular tutor/student
2. Run the program
3. Export the printed ideal student-tutor matches
4. Manually double check that the algorithm has not produced any unreasonably low matches (level that is acceptable is subjective to program administrator)

# Appendix H: Main Storyboard




# Appendix I: Research Quizzes and Questionnaires Links

Research Quiz 3rd-7th Grade

Research Quiz 8th Grade

Mentor Questionnaire

Mentee Questionnaire

# Appendix J: Algorithm Code

## Main Function

```
function [final_match]=DTC2_Matching_Algorithm(STMatrix, thresh)
% Input data
% STMatrix=input('Input the Student-Tutor Matrix');
% thresh=input('What is the total match threshold?');
tic
% Calculate number of students and tutors
num_stud=size(STMatrix,1);
num_tut=size(STMatrix,2);
stud_per_tut=zeros(num_tut,1);
ult_matrix=STMatrix;

% Preallocations
tut_status=zeros(num_tut,1);
stud_status=zeros(num_stud,1);
final_match=zeros(num_stud,3);
final_match(:,1)=(1:num_stud)';

% Generate initial guess
while any(stud_status==0)

[match_vec,match_value,stud_status]=assignmax(STMatrix,stud_status,tut_sta
tus);
% Remove lowest match students
    for i=find(tut_status==0)'
        stud_per_tut(i)=sum(match_vec(:,2)==i)+stud_per_tut(i);
        student_numbers=match_vec(match_vec(:,2)==i,1);
        if stud_per_tut(i)==4
            tut_status(i)=1;
        end
        for j=1:stud_per_tut(i)-4
            [~,excess_student]=min(match_value(match_vec(:,2)==i));
            match_vec(student_numbers(excess_student),2)=0;
            match_value(student_numbers(excess_student))=0;
            tut_status(i)=1;
            stud_status(student_numbers(excess_student))=0;
            student_numbers(excess_student)=[];
            if j==1
                stud_per_tut(i)=4;
            end
        end
        final_match(student_numbers,2)=i;
        final_match(student_numbers,3)=ult_matrix(student_numbers,i);
    end
```

```
    if any(stud_status==0)
        STMatrix=ult_matrix(stud_status==0,tut_status==0);
    else
        continue
    end
end

% Calculate total match
total_match=sum(final_match(:,3));

% Hill climbing algorithm
j=1;
while  j<1000000000 && total_match < thresh
    temp_final_match=randswap(final_match,tut_status,ult_matrix);
    if sum(temp_final_match(:,3))>total_match
        final_match=temp_final_match;
        total_match=sum(temp_final_match(:,3));
    end
    j=j+1;
end

% Printing the Results
for i=1:num_tut
    final_num_stud=sum(final_match(:,2)==i);
    if final_num_stud==0
        fprintf('Tutor %i has 0 students\n',i)
    else
        fprintf('Tutor %i has %i students:',i,final_num_stud)
        final_studs=find(final_match(:,2)==i);
        for j=1:final_num_stud-1
            fprintf('Student %i, ',final_studs(j))
        end
        fprintf('Student %i',final_studs(end))
        fprintf('\n')
    end
end
toc
end
```

## Matrix Reducer

```
function [match_vec,match_value,stud_status] =
assignmax(STMatrix,stud_status,tut_status)
%ASSIGNMAX Assigns each student to their max value tutor
num_stud=size(STMatrix,1);
match_vec=zeros(num_stud,2);
match_value=zeros(num_stud,1);
```

```
match_vec(:,1)=find(stud_status==0);
tut=find(tut_status==0);
j=1;
for i=find(stud_status==0)'
    [match_value(j),match_vec(j,2)]=max(STMatrix(j,:));
    match_vec(j,2)=tut(match_vec(j,2));
    stud_status(i)=1;
    j=j+1;
end
end
```

## Random Step for Hill-Climb

```
function [temp_final_match] = randswap(final_match,tut_status,ult_matrix)
%RANDSWAP
old_stud=randi([1 size(final_match,1)]);
old_tut=final_match(old_stud,2);
new_tut=randi([1 length(tut_status)]);
temp_final_match=final_match;
while new_tut==old_tut
    new_tut=randi([1 length(tut_status)]);
end
if tut_status(new_tut)==1
    new_tut_studs=find(final_match(:,2)==new_tut);
    new_stud=new_tut_studs(randi([1 4]));
    temp_final_match(old_stud,2)=new_tut;
    temp_final_match(old_stud,3)=ult_matrix(old_stud,new_tut);
    temp_final_match(new_stud,2)=old_tut;
    temp_final_match(new_stud,3)=ult_matrix(new_stud,old_tut);
else
    temp_final_match(old_stud,2)=new_tut;
    temp_final_match(old_stud,3)=ult_matrix(old_stud,new_tut);
end
end
```