National Federation of the Blind

Spatial Ability Blind Engineering Research (SABER):

2021 NFB EQonline (Engineering Quotient) Program

Research and Evaluation Report

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Executive Summary

Introduction

The National Federation of the Blind (NFB), in partnership with scholars from Utah State University and educators from the Science Museum of Minnesota (SMM), has developed the Spatial Ability and Blind Engineering Research (SABER) project to assess and improve the spatial ability of blind teens in order to broaden their participation in STEM fields. The goals of the project include:

1. Develop and investigate the reliability of a tactile instrument to test blind and low vision youths' spatial ability levels.
2. Contribute to the knowledge base of effective practices regarding informal STEM education for the blind, particularly relating to the development of spatial reasoning abilities.
3. Educate families, blind youth, and museum personnel about the techniques, tools, and instructional practices rooted in problem solving to effectively develop spatial ability skills in blind youth in informal STEM-learning settings.
4. Incorporate promising techniques, tools, and instructional practices from the developed interventions into ongoing programming for both blind and sighted learners.

Reliability calculations on the Tactile Mental Cutting Test have been developed at an introductory stage. This test was a major product of the original proposal to NSF. In the last year of the project, participant numbers are seen increasing for this instrument and final reliability calculations will be conducted in the final year of the project.

Due to the ongoing COVID-19 pandemic, the 2021 NFB Engineering Quotient (EQ) program was conducted virtually online from July 5 through July 30, 2021 with 35 participants. In addition to exploring the extent to which the 2021 EQ program helped to address the overall goals of the NFB SABER project, the research and evaluation team collaborated to collect, analyze, and report findings on how blind learners build vocabulary, meaning, and understanding of spatial thinking concepts and skills in a synchronistic digital environment.

Methods

Of the 35 2021 NFB EQonline program participants, 13 provided parent consent or individual assent to participant in the program research and evaluation. The research and evaluation team members combined efforts for this report and used the following approaches to collect and analyze the data:

1. Pre-Program Participant Interviews
2. Pulse Participant Interviews
3. Session Observations
4. Post-Session Participant Interviews
5. Post-Program Participant Questionnaire

There are no data on spatial ability performance because the tactile spatial ability test was not able to be delivered with COVID-19 restrictions.

Findings for EQonline

The findings represent perceptions of a sub-group of the 2021 NFB EQonline program that include those participants (13 of the 35) who provided parent consent and/or individual assent for participating in the program research and evaluation. Therefore, these findings are not intended to be generalized to all participants. Rather, they provide a sense of and insights into the participant experience.

Program participants' perceptions of the biggest challenges for blind people who want a career in STEM include:

- Interactions with sighted persons including building social and professional connections with others in the field, working with others who are not knowledgeable about people who are blind, and perceiving that others will think they are "stupid" just because they are blind.
- Other perceived challenges relate to access of materials and instruments needed to accomplish tasks, as well as using some of the technology that would be required.

Participants' perceptions of advantages and disadvantages prior to engaging virtually in the 2021 NFB EQonline program:

- Advantages
  - Anyone can essentially participate in the program, as long as they have a computer connection
  - The convention would be easier to attend virtually
  - No travel requirements and not having to leave their home to participate in the program
  - What technology can provide, including having more access to information via computer
- Disadvantages
  - Perceived challenges to social interaction, having casual conversations with other participants, and just getting to know other participants better
  - Thinking the program would be less "hands-on" compared with attending in person
  - Not having someone to observe whether participants are successfully accomplishing activity tasks

How blind learners build vocabulary, meaning, and understanding of spatial thinking concepts and skills in a synchronistic digital environment:

- Used different types of spatial language to describe spatial features, including using *directional words*, *geometric ideas*, and *reference points*.
- Valued *specific, succinct instruction* as part of the program activities.
- Said that it was helpful to have *multiple descriptions* when receiving instructions.

- Employed different strategies for success during the program that helped them mitigate challenges. These strategies included *different types of preparation*, *cognitive strategies*, *tactile strategies*, and *analytical approaches.*
- Used *cognitive strategies*, such as generating *mental images* that allowed them to *visualize objects or models in two or three dimensions*.
- Used *tactile strategies* such as "[feeling] crease lines" when they were performing various paper folds.
- Used *analytical strategies*, such as *counting features* (e.g., "it should look like a square with 4 folded edges with 4 triangles with their tips meeting in the center"), using *measurement terms* (e.g., "make the egg folded edge cut two inches away from edge"), and performing *calculations* (e.g., "[I] did calculations for the lid and how it fit").

Program outcomes for a sub-population of the 2021 NFB EQonline participants:

- They increased their confidence in their ability to participate in engineering projects or activities.
- The program helped them to understand engineering better,
- Increased their interest to study science and engineering,
- Increased their ability to understand geometric concepts and engineering drawings, and
- Increased their interest in pursuing a STEM career.

Discussion

How blind learners build vocabulary, meaning, and understanding of spatial thinking concepts and skills in a synchronistic digital environment

This report describes the different types of spatial language that were used by blind youth as they completed paper folding and engineering drawing activities during the 2021 NFB EQonline program. It also reveals how the blind participants used different strategies for success during the program, such as leveraging their prior knowledge about STEM and origami and using cognitive, tactile, and analytical approaches to combat challenges.

The 2021 NFB EQonline program provided blind youth with an opportunity to engage with paper folding and engineering drawing activities. The program taught the participants different types of spatial language and vocabulary through engaging guided activities that allowed students to be creative while deepening their understanding of STEM topics. Exposing blind youth to these types of activities and supporting them in developing spatial thinking skills may encourage more individuals from this population to develop technical literacy and pursue STEM pathways.

The extent to which the 2021 EQ program helped to address the overall goals of the NFB SABER project

Blind youth perceive that interactions with sighted persons including building social and professional connections with others in the field, working with others who are not knowledgeable about people who are blind, and perceiving that others will think they are

“stupid” just because they are blind, are potential challenges for them pursuing a STEM career. Other perceived challenges relate to access of materials and instruments needed to accomplish tasks, as well as using some of the technology that would be required. These findings help contribute to the knowledge base of effective practices regarding informal STEM education for the blind, particularly relating to the use and development of spatial reasoning abilities and vocabulary used when engaging with and navigating spatial activities such as origami. Effective practices may need to include forethought on the spatial terminology selected and used by instructors concerning materials and demonstrations. Effective practices may also need to include educational and learning style approaches that help address social issues and strategies when working in the field with sighted co-workers, building professional networks, and training on technology and accessing other resources that will support blind persons pursuing a career in STEM, as well as supporting those currently in the field.

A sub-population of the 2021 NFB EQonline program participants indicated that the program helped to increase their confidence in their ability to participate in engineering projects or activities, felt the program helped them to understand engineering better, increased their interest to study science and engineering, increased their ability to understand geometric concepts and engineering drawings, and increased their interest in pursuing a STEM career. This indicates that the 2021 NFB EQonline program can help to advance incorporating promising techniques, tools, and instructional practices from the developed interventions into ongoing programming for both blind and sighted learners.

Overall, providing blind students with opportunities to engage with STEM content, such as with programs similar to the 2021 NFB EQonline program, may encourage more students from this population to pursue engineering pathways or endeavor to develop engineering and technical literacy.

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Introduction

The National Federation of the Blind (NFB), in partnership with scholars from Utah State University and educators from the Science Museum of Minnesota (SMM), developed the Spatial Ability and Blind Engineering Research (SABER) project to assess and improve the spatial ability of blind teens in order to broaden their participation in STEM fields. The goals of the project include:

1. Develop and investigate the reliability of a tactile instrument to test blind and low vision youth spatial ability levels.
2. Contribute to the knowledge base of effective practices regarding informal STEM education for the blind, particularly relating to the development of spatial reasoning abilities.
3. Educate families, blind youth, and museum personnel about the techniques, tools, and instructional practices rooted in problem solving to effectively develop spatial ability skills in blind youth in informal STEM-learning settings.
4. Incorporate promising techniques, tools, and instructional practices from the developed interventions into ongoing programming for both blind and sighted learners.

Reliability investigations have been conducted throughout the year on the projects development of a Tactile Mental Cutting Test (TMCT). Continued work in this last year of the project will focus on increasing participant numbers on the TMCT. Initial findings, as presented in Lopez et al. (2020) and Goodridge et al. (2021) have been published concerning the validity and reliability of this instrument.

Due to the ongoing COVID-19 pandemic, the NFB 2021 EQ program was conducted virtually on-line from July 5 through July 30, 2021. In addition to exploring the extent 2021 EQ program helped to address the overall goals of the NFB SABER project, the research and evaluation team collaborated to collect, analyze, and report findings on how blind learners build vocabulary, meaning, and understanding of spatial thinking concepts and skills in a synchronistic digital environment.

Prior to beginning the EQonline program, participants were mailed kits of instructional materials including workbooks and supplies that supported origami paper folding and engineering drawing activities. Included in these kits of materials was a vocabulary list of terminology that was used throughout the paper folding activities in the program. This list consisted of basic origami terminology such as “mountain fold,” “valley fold,” “raw edge,” and “folded edge.”

Each EQonline session included a community-building activity at the start of the session (e.g., discussing a current favorite movie or hobby). Program participants were split into two groups, with one group attending the paper folding session first and the second group attending the engineering drawing session first. After a 30 minute break, each group then completed the session that they had not yet participated in.

The 2021 NFB EQonline program had a total of 35 registered participants, of which 13 provided parent consent and/or individual assent to participate in the research and evaluation. This report describes the methods that were used to collect the research and evaluation data, the findings, and a discussion.

Methods: Spatial Ability Test Development

Methods for the development and investigation of validity and reliability for the Tactile Mental Cutting Test (TMCT) spatial ability instrument can be seen in Ashby et al. (2018), Lopez et al. (2020), and Goodridge et al. (2021).

Methods: Summer EQonline Research and Evaluation

The external evaluator collected data from the 2021 NFB EQonline program participants using three different methods:

1. **Pre-Program Participant Interviews:** The evaluator designed and conducted interviews with 2021 NFB EQonline participants before they engaged in the program (see Attachment A). Participants were contacted via email, and in some cases via text message, to schedule Zoom interviews with the evaluator. The interview used open-ended questions that included participants' motivation for participating in the program, their involvement in STEM-related extracurricular activities, their perceptions of the challenges a blind person might face pursuing a STEM career, and their thoughts on what might be the advantages and disadvantages to engaging in a virtual program versus one that is in-person. A total of seven interviews were completed.
2. **Pulse Interviews**: Pulse interviews are a set of questions that engage participants in brief conversation (no more than 3 minutes) to get an immediate sense, or "pulse" of their perceptions on a specific subject (see Attachment B). In the case of the 2021 NFB EQonline program, the evaluator conducted a total of eight pulse interviews with program study participants during a break after three different sessions throughout the month of the program. Individual session participants were asked to comment on what they liked about the session, experiencing the session virtually, and what could be improved. Participant perceptions were shared with the EQonline session facilitators for them to get a sense of participants' experiences with individual sessions and for possible adjustments to facilitation.
3. **Post-Program Questionnaire:** The evaluator designed and disseminated via email a post-EQonline program questionnaire (see Attachment C) to a total of 13 program study participants who had parent consent and/or who had provided individual assent to participate in the 2021 NFB EQonline research and evaluation study. The questionnaire explored participants' thoughts after participating in the program including increased interest to study science and engineering, understanding of geometric concepts and engineering drawings, and confidence in participating in engineering projects and activities. The evaluators sent two emails and one text reminder to these participants to complete the questionnaire. Seven of the

13 participants chose to complete the questionnaire. Responses to the questionnaire were analyzed using descriptive statistics.

The Evaluators and Researchers collected data from the 2021 NFB EQonline program using:

4. **Session Observations:** Evaluators and researchers used an observation instrument (see Attachment D) during four of the 2021 NFB EQonline sessions to record aspects of the activity. They observed where program study participants used specific words, their understanding of specific words, and strategies that participants used to address these areas of word confusion and/or understanding. The research team analyzed the field notes from these observations using qualitative coding procedures.
5. **Post-Session Participant Interviews:** During the 30 minute breaks between the paper folding and drawing sessions of some of the activities, researchers and evaluators solicited interviews from participants that consented in the research study. The researcher or evaluator and participant moved into a separate Zoom breakout room to conduct the interviews (see Attachment E), which lasted between three and ten minutes. Participants were asked questions, such as, "What words used in the activity did you find most difficult to understand?" and "What words used in the activity made sense to you and were easy to understand?" The researchers analyzed the participant interview notes using qualitative coding procedures.

Findings: EQonline Research and Evaluation

Pre-Program Interviews

The evaluator was able to conduct Zoom interviews with seven of the 13 2021 NFB EQonline program participants who provided parent consent and/or individual assent to participate with the research and evaluation. The results of the pre-program interviews are not intended for generalizing to the entire 2021 NFB EQonline participant population. However, they do provide a sense of some participants' thinking before engaging in the program.

Motivation to participate in the 2021 EQonline program

When asked why they chose to participate in 2021 NFB EQonline program, six of the seven were *intrinsically* motivated including:

- It aligns with their interest in STEM
- Wanting to learn something new in general
- Wanting to learn more about origami
- Wanting to learn a new skill
- Thinking the program would be less stressful than taking a formal classroom course
- It might help them to decide which area of engineering to pursue.

One participant was *extrinsically* motived by his mother encouraging him to participate in the program, because she thought it would interest him.

Participation in STEM-based extracurricular activities

Four of the participants indicated they had not participated in any STEM-based extracurricular activities prior to participating in the 2021 NFB EQonline program. Three others indicated they had, including being a part of a robotics competition though a local robotics club, being involved in a statewide space consortium, and attending the NFB convention in the past.

The biggest challenge for blind people who want a career in STEM

Participant perceptions varied on what they thought was the biggest challenge for blind people who want to pursue a career in STEM. These included:

- Building social and professional connections with others in the field
- Knowing when and who to ask for help
- Figuring out how to do things differently and in new ways from those who are sighted
- Needing co-workers to be patient with a person who is blind
- Working with others who are not knowledgeable about working with people who are blind
- Perceiving that others will think they are "stupid" just because they are blind
- Access to materials and instruments needed to accomplish tasks, such as microscopes
- Using some of the technology that would be required

Possible advantages and disadvantages of participating virtually in the 2021 NFB EQonline program

When asked what they thought might be the advantages and disadvantages of participating virtually in the 2021 NFB EQonline program, participant comments varied.

The main advantage to EQ being virtual mostly had to do with greater accessibility:

- Anyone can essentially participate in the program, as long as they have a computer connection, and the convention would be easier to attend virtually
- No travel requirements and not having to leave their home to participate in the program
- What technology can provide, including having more access to information via computer
- Having more time to think before responding to questions

The biggest disadvantages included:

- Perceived challenges to social interaction, having casual conversations with other participants, and just getting to know each other better
- The program being less "hands-on" compared with attending in person
- Not having someone to observe whether participants are successfully accomplishing activity tasks

Pulse Interviews

The evaluator conducted pulse interviews with program study participants after three different sessions. The results of the pulse interviews are not intended for generalizing to the 2021 NFB

EQonline participant population, but rather to provide some insight from some of the participants as they experienced the program.

The first pulse interviews were conducted on July 12th with two program participants who engaged in the origami paper-folding session. Both participants said they liked that the activity was challenging but not too challenging. One participant said they had difficulty building the cube, not because the directions were unclear, but rather it was an issue of skill (i.e., making their fingers do what they wanted to do and knowing where to place fingers), especially when it came to sliding a flap under another flap.

When it came to participating in the session virtually, one participant said it would have been helpful if the session was in-person so that they could get immediate feedback if they were doing the folding correctly (i.e., having someone near them who could check out their folds and redirect if they were headed in the wrong direction). The other participant said that it would have been helpful if the session had provided more detail during the instruction and when demonstrating the folding. Maybe providing the instruction stepwise, such as the session facilitator saying "Step One" and then describing what they were doing, and then following that up with, "Is this clear?"

The second pulse interviews were conducted on July 16th with two participants who had attended the facilitated drawing class. One participant said they liked the spatial reasoning that was provided to use a two-dimensional grid to design a three-dimensional object. The session was also designed to use cubes to design their object. One participant did the drawing exercise without using the cubes and indicated that this resulted in them needing to mentally do more visualization of the object in their mind.

One participant said that doing the session virtually got them thinking of better ways to describe things over Zoom. For example, describing a figure that looked the same from three different angles. It helped when the session facilitator talked about "rotating" an object 90 degrees from one direction, and then indicating which cubes a person was looking at from that direction.

One participant said they would have liked to have been able to talk with more participants in the session. Just hearing how others did things would have helped them to describe how they accomplished the drawing exercise.

The third pulse interviews were conducted on July 21st with four participants who had attended the math session that focused on origami. One participant said they enjoyed learning the rules that govern whether an origami paper object can be folded flat or not. Another participant indicated they liked the topic of math, since it is of personal interest, and liked the concept of the math behind origami folds.

While one participant indicated that "it was not a big deal doing it [the session] virtually," another participant said it might have been easier to do the folding if the session was conducted in-person so that participants could have been able to help-out each other. A third participant

commented that because the session was virtual, there was not anyone to check if they were doing the session activity correctly.

One participant said they had not previously thought about math when thinking about origami. Another commented that the next time they do origami folding, they will have math in mind. The only comment for improving the session was maybe to provide more instructions on folding the patterns, or even repeating the instructions of what was needed. Because everyone learns differently, this would help to ensure everyone was able to follow the instructions.

Observations and Interviews

Results from the analysis of the session observations and transcripts from post-session interviews revealed how the 2021 NFB EQonline program participants used spatial language while completing the program activities. The analysis also provided insights into aspects of the program that they found helpful in addition to different strategies that the blind participants used during the program to mitigate any potential challenges that they faced.

Some types of spatial language that were identified included *directional words*, *geometric ideas*, and *reference points*. Directional words included words such as "up/down," "right/left," and cardinal directions (e.g., north, south, east, and west). Geometric ideas included words pertaining to the geometry of a shape, including "half," "middle," "center," and "parallel." Reference points included language that spatially related objects to one another or from one point on an object to another point. This included words such as "inside/outside," "across," and "top/bottom." In addition to these types of spatial language, participants also used different kinds of origami terminology as they engaged in the EQ program activities. They used terminology as they were defined in the vocabulary lists (e.g., mountain fold, valley fold, cupboard fold) that they received as part of the program materials, as well as using their own definitions for certain words. For example, participants used the phrase "folded edge" synonymously with the word "crease" to describe a particular aspect of an origami piece.

One aspect of the program that the blind participants found particularly helpful was when the instructors used *specific, succinct instruction* when walking through the lessons and activities. Some participants commented that they benefited from having instructions that were concise and to-the-point rather than being too wordy. Specific instructions were also regarded as helpful to understanding the activities, such as describing exactly what the final result of the origami piece should like after a particular fold. Participants also described how using multiple ways of describing a particular procedure (e.g., folding "east to west" or "left to right") was helpful to their understanding.

Findings from the analysis also revealed helpful strategies that the blind participants employed that allowed them to be successful throughout the 2021 NFB EQonline program. Participants entered the program with varying levels of *prior knowledge* and experience with STEM activities and leveraged this prior knowledge accordingly. For example, some students mentioned having had taken STEM classes in their high school, while other students mentioned that they had

worked on origami projects before. Students also prepared themselves for the EQonline activities by making use of the time outside of the synchronous sessions to complete activities or assignments that prepared them for the next synchronous group session.

Program participants also employed various strategies to help them mitigate any potential challenges that they may have experienced. Some challenges that the participants mentioned included having *difficulty with the virtual format* of the program, having *difficulty understanding the terminology* used in the program, and having trouble *visualizing models in two and three dimensions.* These strategies included *cognitive, tactile,* and *analytical* approaches when working on the program activities.

Cognitive strategies included being able to mentally visualize objects in two and three dimensions and developing mental models of the origami structures they were creating. One activity required students to mentally visualize how common three-dimensional objects, such as a sphere, would be represented in two dimensions (i.e., using a circle). Another activity required students to conceptualize objects in the opposite way by identifying what a two-dimensional drawing represented in three dimensions (e.g., lines on a drawing of a cup to represent the handle).

Tactile strategies included *feeling crease lines* with their fingers as they identified where to make the next fold in a sequence of instructions. Other students *counted features* of objects, such as the number of sides that a shape had after a resulting fold, which would help them determine if they had arrived at the correct result after following a set of instructions.

Last, participants used analytical strategies, such as using *measurement terms* when describing where to perform certain folds (e.g., "make the egg folded edge cut two inches away from edge") and performing *calculations* to ensure multiple parts of an origami model would fit together properly when assembled (e.g., "[I] did calculations for the lid and how it fit").

Post-Program Participant Questionnaire

After repeated attempts by the evaluator to remind participants to complete the online post-program participant questionnaire, only seven of the 13 (who provided parental consent or individual assent to participate in the 2021 NFB EQonline program research and evaluation) did so. Therefore, the results are not intended for generalizing to the 2021 NFB EQonline participant population, but to provide some insight to program outcomes for some of the participants.

All seven respondents agreed or strongly agreed that the 2021 NFB EQonline program increased their confidence in their ability to participate in engineering projects or activities. Most (6 of 7) agreed or strongly agreed that the program helped them to understand engineering better, increased their interest to study science and engineering, increased their ability to understand geometric concepts and engineering drawings, and increased their interest in pursuing a STEM career. The majority (5 of 7) agreed or strongly agreed that the program made them think more about what they will do after graduating from high school. Many (4 of 7) neither agreed nor

disagreed (with 3 agreeing) that the program helped them to better understand their own career goals.

Discussion

How blind learners build vocabulary, meaning, and understanding of spatial thinking concepts and skills in a synchronistic digital environment

The work presented in this report provides valuable insights into how blind youth conceptualized different spatial concepts and used spatial language to accomplish the goals of the various 2021 NFB EQonline activities. This work also demonstrates how blind youth used various strategies to mitigate challenges that they experienced in the online learning environment while completing these activities.

The research and evaluation team found evidence of the blind participants using different types of spatial language, including words describing geometric features (e.g., half, vertex, middle, parallel); directional words (e.g., right/left, up/down); and reference points (e.g., across, edge, front/back). Participants were also observed to be using different types of strategies for success in the program, such as leveraging their prior knowledge and using tactile strategies. In addition, the blind participants used various origami terms that were included in the vocabulary list provided to them. They used terms such as "mountain fold" and "valley fold" when describing how they folded a certain shape or when they were instructing their fellow peers on how to fold an object.

Origami and paper folding activities, like those that were part of the 2021 NFB EQonline program, lend themselves as a potential way for educators to target and improve students' spatial ability. Origami encourages students to conceptualize various two- and three-dimensional geometric shapes and requires them to mentally and physically manipulate these shapes by folding, rotating, and assembling them into three-dimensional models. Origami and paper folding activities allow students to have fun and explore their creativity while also supporting spatial skill development. Through hands-on, tactile activities that teach blind students different kinds of origami vocabulary and encouraging them to use spatial language relating to geometric features, these students may develop more sophisticated spatial thinking and reasoning skills.

The research and evaluation team's efforts to explore the spatial ability of blind students through the paper folding and engineering drawing activities in the 2021 NFB EQonline program is one of the first of its kind. There have been few, if any, prior research studies that have investigated how these types of activities impact spatial reasoning, thinking, and language in blind populations. Through this program, blind youth were introduced to different types of spatial language through guided instruction and interactive activities. This type of intervention may be able to enhance blind students' spatial reasoning skills that may then transfer to other areas of their lives. By having opportunities to engage with STEM content and refine their spatial skills, blind students may be more encouraged to pursue STEM pathways or develop technical literacy.

The extent the 2021 EQ program helped to address the overall goals of the NFB SABER project

One goal of the NFB SABER project is to contribute to the knowledge base of effective practices regarding informal STEM education for the blind, particularly relating to the development of spatial reasoning abilities. The sample size of those who participated in the research and evaluation of 2021 NFB EQonline program was limited (13 of the 35 total). While the findings of the pre-program participant interviews, the pulse interviews, and post-program participant questionnaire cannot be generalized to all 2021 NFB EQonline program participants, they do provide some helpful insights.

For example, the biggest challenges for blind people who want a career in STEM involve perceptions and interactions with sighted persons, including building social and professional connections with others in the field, working with others who are not knowledgeable about working with people who are blind, and perceiving that others will think they are "stupid" just because they are blind. Other perceived challenges relate to access of materials and instruments needed to accomplish tasks, as well as using some of the technology that would be required. These findings help contribute to the knowledge base of effective practices regarding informal STEM education for the blind, particularly relating to the use and development of spatial reasoning abilities and vocabulary used when engaging with and navigating spatial activities such as origami. Effective practices may need to include forethought on the spatial terminology selected and used by instructors concerning materials and demonstrations. Effective practices may also need to include educational and learning style approaches that help address social issues and strategies when working in the field with sighted co-workers, building professional networks, and training on technology and accessing other resources that will support blind persons pursuing a career in STEM, as well as supporting those currently in the field.

The pulse interviews revealed that for some blind participants, detailed and stepwise instructions for accomplishing specific tasks was helpful. For others, doing the EQonline sessions virtually had them thinking of better ways to describe things over Zoom. The findings of the post-program participant questionnaire indicated that a sub-population of the 2021 NFB EQonline program participants increased their confidence in their ability to participate in engineering projects or activities, felt the program helped them to understand engineering better, increased their interest to study science and engineering, increased their ability to understand geometric concepts and engineering drawings, and increased their interest in pursuing a STEM career. This has implications for accomplishing another goal of the SABER project of incorporating promising techniques, tools, and instructional practices from the developed interventions into ongoing programming for both blind and sighted learners.

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Attachment A: Pre-Program Participant Interviews

Date: _____
Participant: _____

Hi,

This is Gary Timko. I'm working with the organizers of the 2021 NFB EQonline program to better understand your experience with the program, I'd like to talk to you for about 15 minutes. Your participation is voluntary and your responses are completely confidential. You can stop at any time. Do you have some time to answer questions?

1. Why did you choose to participate in the 2021 EQonline program?
2. Have you participated in any STEM-based extracurricular activities before the 2021 NFB EQonline program?
3. What do you see as the biggest challenge for blind people who want a career in STEM?
4. What do you think are the possible advantages and disadvantages of participating virtually in the 2021 NFB EQonline program?

Attachment B: Pulse Interviews

Date: _____
Session: _____

1. In general, what did you like or dislike about today's sessions?
2. How did it work for you doing this session virtually in these sessions? What did you like about and not like doing this virtually?
3. What are two to three things that stick with you about what you learned today?
4. How might today's sessions be improved or changed?

Attachment C: Post Questionnaire

NFB Spatial Ability POST- EQO2021

To help the organizers of the NFB EQ program better understand your experience, please take 15 minutes to answer the following questions. There are 10 questions. To increase the contrast of the questions, it is recommended you access the survey with Chrome or Safari.
You may decide to quit or skip any questions that you don't feel comfortable answering. This is not graded. There are no right or wrong answers.

This set of questions focuses on how you feel about science and engineering now that you've participated in NFB EQ online 2021.

Tell us what you think about these statements by selecting the number that indicates how much you disagree or agree with these statements. Enter a 1 if you Strongly Disagree with this statement, 2 if you Disagree, 3 if you Neither Disagree nor Agree, 4 if you Agree, and 5 if you Strongly Agree.

NFB EQ online 2021 helped me to understand engineering better.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5 Strongly Agree

NFB EQ online 2021 led me to a better understanding of my own career goals
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

NFB EQ online 2021 increased my interest to study science and engineering
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

NFB EQ online 2021 increased my ability to understand geometric concepts and engineering drawings.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

NFB EQ online 2021 made me think more about what I will do after graduating from high school.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree

5. Strongly Agree

NFB EQ online 2021 made me think about different classes I might take in school than I had planned, including college.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

NFB EQ online 2021 increased my confidence in my ability to participate in engineering projects or activities.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

NFB EQ online 2021 increased my interest in pursuing a STEM career.
1. Strongly Disagree
2. Disagree
3. Neither Disagree nor Agree
4. Agree
5. Strongly Agree

For this evaluation, accessible means that a given material or task was designed with blind/low-vision people in mind. The following elements are typically part of classroom learning. We want to know if these elements are accessible for you in your school. Tell us what you think about these statements by selecting the number that indicates how accessible you believe these elements are. Enter a 1 if you believe the element is inaccessible/can't be used at all, 2 if it's really hard to use but you can, 3 if it's ok to use with some modifications, 4 if you can use it, but it could be made better if there was one modification, and 5 if it's completely accessible/easy to use. If an element is typically not available for you, please rate it as 1-inaccessible.

In your school, teacher-delivered content (lectures, instructions, etc.)

1. Inaccessible
2. Hard to use, but you can
3. O.K. to use with some modification
4. Can use it, but could be better with one modification
5. Accessible

In your school, written materials (books, handouts, workbooks)

1. Inaccessible
2. Hard to use, but you can
3. O.K. to use with some modification
4. Can use it, but could be better with one modification
5. Accessible

In your school, drawing materials (sensational blackboard, drafting table)

1. Accessible
2. Hard to use, but you can
3. O.K. to use with some modification
4. Can use it, but could be better with one modification
5. Accessible

Now, we'd like you to use the same rating scale to rate the degree of accessibility for these elements for NFB EQ online 2021. Again, if an element was not available, please rate it as 1-inaccessible.

For NFB EQ online 2021, teacher-delivered content (lectures, instructions, etc,)

1. Inaccessible
2. Hard to use, but I was still able to use it
3. O.K. to use, but needed some modification
4. Used it, but would have been better with one modification
5. Accessible

For NFB EQ online 2021, written materials (books, handouts, workbooks)

1. Inaccessible
2. Hard to use, but I was still able to use it.
3. O.K. to use, but needed some modification
4. Used it, but would have been better with one modification
5. Accessible

On a scale of 1 to 5, where 1 represents "No Interest" and 5 represents "Very high interest", how much interest do you have in pursuing a career in a science, technology, engineering, or mathematics-related field?

Interest in pursuing a STEM career

1. No interest
2. Low interest
3. Moderate interest
4. High interest
5. Very high interest

What is one thing your school has that NFB EQ online 2021 could use?

_____
_____
_____

What is one thing NFB EQ online 2021 has that school could use?

_____
_____
_____

Was there anything about NFB EQ online 2021 that you found accessible that is typically inaccessible to you? If so, what was that?

_____
_____
_____

If you were in charge, how would you change NFB EQ online 2021?

_____
_____
_____

Is there anything else you'd like to share about your experiences with NFB EQ online 2021?

_____
_____
_____

Attachment D: Observation Data Collection Instrument

NFB EQ 2021 Activity Observation Instrument

Date: _____

Time: _____

Activity: _____

Observer Name: _____

Words	Context	Possible meaning
Example: *Front*	Example: *Participant is describing a 3-D snap cube object*	Example*: Side of the 3-D snap cube object that faces the participant; side of the 3-D snap cube closest to the participant*

1. Comment on any aspects of the activity where participants appeared confused by specific words, use of specific words, understanding of specific words.
2. Describe strategies that participants used to address these areas of word confusion and/or understanding.

Attachment E: Post Activity and Observation Participant Interview

1. How easy or difficult was it for you to do the activity?

2. What words used in the activity did you find most confusing or difficult to understand? Why?

3. What words used with the activity made sense to you and were easy to understand?

4. Were there any additional words, descriptions, or information that helped you to understand and do the activity? What was this, and how did it help?