Paper ID #19662

Native Spanish-Speaking Adolescents' Information Gathering Processes While Solving Problems through Engineering

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Native Spanish-Speaking Adolescents' Information Gathering Processes While Solving Problems through Engineering (Fundamental)

In order to produce viable engineering designs, engineers must gather, correctly interpret, synthesize, and apply accurate and sufficient information from a variety of sources.[1, 2] The information gathering process is complex even for the most experienced engineers, but this process can be even more daunting to adolescents who often may not understand advanced scientific and technical texts due to their challenging vocabulary and syntax.[3] In sum, adolescents—especially those who are relatively new to the English language—may benefit from tailored instructional supports as they gather and interpret information while engineering.[4] Before these instructional supports can be developed, however, researchers must first understand adolescents' engineering design activity to identify possible ways in which teachers can build on their students' existing strengths while meeting their specific needs.

The purpose of this exploratory study was therefore to describe the ways in which adolescents, all of whom spoke Spanish as a first language, approached the information gathering stage of the engineering design process as they sought to solve authentic, community-based problems through engineering. In this paper, we refer to the students as emerging bilinguals to connote that they all spoke a first language (Spanish) and that they had achieved varying degrees of proficiency in a second language (English). By identifying the assets and challenges faced by the adolescents, this foundational research provides an early knowledge base from which researchers and practitioners can draw as they seek to develop instructional approaches that draw from linguistically diverse adolescents' existing strengths and skills, while simultaneously addressing potential challenges during the information gathering stage of the engineering design process.

Related Literature

Recently, national K-12 standards and frameworks asserted that youth should engage in engineering design processes.[5,6] Descriptions of these processes vary, but they tend to share several commonalities: *problem scoping*, which includes gathering information and identifying relevant criteria and constraints; *developing solutions*, which includes brainstorming and evaluating solution elements; and *realizing solutions*, which includes communicating solutions to clients, possibly through the use of physical models or prototypes in addition to writing. [1,7]

All elements of the engineering design process are essential for the production of a high-quality final design, but devoting adequate time to the problem scoping stage is associated with higher quality products.[1] Indeed, Atman and colleagues found that experts gathered more information, and more types of information, as opposed to novices when asked to solve a problem through engineering, a finding that was confirmed in later studies with high school students.[8] Bursic and Atman suggested that, in order to produce quality designs, engineers must gather information under several categories.[9] For instance, engineers who design a playground must collect information about the available budget; labor availability and cost; the local area, such as the location of other similar parks; utilities, such as the location of water pipes; and the availability of materials. Engineers must know where to find this information; must evaluate the quality of information that they find (e.g., is the map of the neighborhood outdated?); and must apply the information to their final designs.

Although problem scoping is essential to engineering design, few studies have addressed how adolescents—especially those who speak English as a second language—gather information when they seek to solve problems through engineering. The purpose of this study was therefore to describe the information gathering activity of adolescents, all of whom spoke English as a second language, at this stage of the engineering design process.

By describing this type of activity, we hoped to identify ways in which engineering instruction can more rigorously account for the assets that emerging bilingual students bring to the engineering design process, as well as the challenges that are associated with language learning during this reading-intensive stage of the engineering design process. Unlike many previous studies, which have been conducted in labs in response to imaginary problems posed by researchers, [1,8,10] we sought to describe youths' information gathering processes as they worked on more authentic engineering challenges over time. By 'authentic,' we mean problems with no clear correct single solution, which are co-determined by participants as they negotiate with each other and relevant stakeholders, such their clients. [11,12] By conducting the study in a naturalistic setting, we hoped to identify contextualized and diverse information gathering processes as opposed to the limited gathering processes available in clinical laboratory settings.

Methods

This study is a secondary analysis of data collected from a multiple case study of seven groups of adolescents (25 people total) as they selected problems in their communities and developed solutions over the course of approximately nine months.[13] Table 1 outlines the different problems that each group sought to address through engineering. We provided each adolescent with a tablet throughout the duration of the project so they could use it to search for information online.

The participants identified themselves as Latino/a and had received ESL (English as a second language) services through their schools. We selected participants who met this criterion because emerging bilinguals face additional difficulties when reading scientific texts in English,[14,15] and we sought to develop a robust model of instruction that would account for potential difficulties they faced, in addition to strengths they possessed by being bilingual, when they gathered information.

Table 1
Description of Groups and Projects

Group Composition	Self-Selected Problem	Outcomes of the Project
Group One Eduardo (male,16) Federico (male, 17) Miguel (male, 16)	Design a user-friendly door for people in wheelchairs at their high school.	Produced visual model; gave presentation to high school administrators and custodians.

Group Two Eva (female, 16) Laura (female, 17) Mateo (male, 15)	Improve and expand a local playground to increase attendance.	Produced visual model; shared PowerPoint presentation with local city council and a civil engineer.
Group Three Ana (female, 16) Noemi (female, 17) Silvia (female, 15) Zoe (female, 17)	Improve an existing device used by veterinarians to restrain feral cats as they receive vaccination shots.	Produced visual model; mailed a letter to the company that sold the existing cat-nabber.
Group Four Emiliano (male, 17) Patricio (male, 14) Samuel (male, 16)	Improve existing water- and cold- resistant shoe for running and playing in the snow.	Produced visual model; sent an email to the company that sold the existing shoe.
Group Five Alisa (female, 15) Carisa (female, 14) Carla (female, 15) Paula (female, 16)	Improve water catchment systems for individual homes in rainy regions of Honduras.	Produced visual model; emailed a PowerPoint presentation to a representative of a non-profit charity concerned with water issues.
Group Six Carmen (female, 17) Dulce (female, 17) Felicia (female, 16) Katie (female, 16)	Improve existing playground swing for children in wheelchairs.	Printed a three-dimensional model; shared a PowerPoint presentation with the head of their city's Parks and Recreation Department.
Group Seven Claudia (female, 17) Seina (female, 16) Sofia (female, 17) Tomás (male, 17)	Improve head rests on tub-based shower chairs for children with disabilities who cannot hold up their heads.	Printed a three-dimensional model and constructed a physical prototype of the design; gave the prototype and a PowerPoint presentation to the caregiver of a boy who used a tub-based shower chair.

We collected three types of data. First, we collected video-recordings from bi-monthly group meetings, during which time the youth gathered information related to the problems. In these video-recordings, we captured the participants' discussions surrounding particular websites they had found. Second, we collected individual monthly interviews with each participant in which we asked questions about the sources they were consulting at home and during the meetings. These interviews were conducted in the participants' home language (Spanish) when necessary. Third, we collected screenshots or photographs of the websites that the youth had visited, and we used them as the basis for conducting concurrent or retrospective protocols in which the adolescents thought aloud as they were gathering information.

We used modified constant comparative analytic methods to analyze the data.[16] As we read randomly-selected data, we began to notice three patterns. First, we noticed that participants tended to prefer asking people for information, as opposed to searching for information through texts. To confirm this pattern in the data, we quantified the pieces of information that participants obtained verbally versus the pieces of information that they obtained through printed or digital materials (e.g., on the Internet). We also quantified the number of times that participants used Spanish or English to obtain information verbally or in writing. Second, we noticed that participants seemed to prefer conducting searches for visual information as opposed to searches for verbal information. To confirm this pattern in the data, we quantified the number of times that participants conducted searches for images as opposed to conducting searches for written information.

Third, we noticed that different groups sought for different types of information as they conducted Internet searches. We inductively developed a coding scheme that described the types of information for which the participants sought (see Table 2). Using this coding scheme, two people independently coded the entire data set and received over 85 agreement in codes, an indication that they were confirmable. [17,18]

Table 2
Codes Related to the Information Gathering Stage of the Engineering Design Process

Code	Definition	Example
Cost	Conduct an Internet search to determine the price of parts, materials, or comparable designs.	Search for “cost of handicapped door” to determine how much it typically costs to purchase and install a door for people in wheelchairs.
Previous Designs	Conduct a search to determine the appearance of other designs that have been used to solve similar problems.	Search for “wheelchair swing” to call up images of previous playground swings that have been used by children in wheelchairs.
Technical References	Conduct an Internet search to determine scientific and mathematical principles relevant to their design.	Search for “muscular dystrophy” to learn more about the physical effects of the disease.
DIY (Do It Yourself)	Conduct an Internet search to determine the processes by which something can be done.	Search for “cat-nabber” and then view tutorial videos on company’s website regarding how to use their cat-nabber.
Measurement	Conduct an Internet search to discover the specific dimensions of a person or object, such as its weight, height, or length.	Search for “how wide is a wheelchair” to gain ideas for how wide a wheelchair swing should be.

Marketing	Conduct an Internet search to determine companies to whom they wanted to market their ideas.	Search for "Columbia shoes" to find contact information for a company to which they hoped to market their shoes.
Neighborhood Opinions	Conduct Internet searches while discovering and using online tools that enable them to reach out to the community.	Search for "make a website" to find possible platforms they could use to make a website on which they could put a community survey.

Findings

Analyses of the data indicated three primary findings. First, most groups preferred to obtain information verbally (primarily in English but also occasionally in Spanish) as opposed to obtaining information in writing. Second, most groups preferred to conduct Internet searches in which they looked for images as opposed to conducting Internet searches in which they looked for written information. Finally, the participants sought for information in categories that differed from categories of information used by professional engineers.[19] In the following section, we elaborate on these three findings.

Finding 1: Most groups preferred to obtain information verbally as opposed to obtaining information in writing.

Most groups preferred to obtain information verbally as opposed to obtaining information in writing (see Table 3). When compared to the pieces of information that they obtained through written mediums (e.g., reading a website), six of the seven groups obtained twice as many pieces of information through oral mediums (e.g., asking their science teacher for help). Ana clearly stated her preference for oral communication. When asked, "What were your thoughts on the engineering project," she gave the following response:

> Overall I thought it was something, a new thing to try. It was, it made me think, and I think that I went to, I discovered new resources to find a solution. I realized that it's better to ask because the internet is just frustrating. So it's better to ask around because it gives you more direct, more of a direct answer.

Consistent with this quotation, her group (Group 1)—which re-designed a cat restraint device—consulted a variety of people to obtain information about their design. For instance, they visited five humane shelters and veterinarians' offices to interview the technicians and doctors there (in English) regarding existing problems with the cat-nabber. Finally, they visited local hardware stores to interview the employees in English about the materials they should use for their engineering design. Because their web searches were not fruitful—in Ana's words, they were "frustrating" and in Noemi's words, they were "confusing"—the youth tended to use their oral language skills (most commonly in English, but also in Spanish) to acquire various types of information from different community members.

Table 3
Number of Pieces of Information Obtained in English and Spanish, Verbally and in Writing

Group	Oral information (English)	Oral information (Spanish)	Written information (English)	Written Information (Spanish)
1	72	4	12	0
2	20	2	70	10
3	145	18	16	0
4	71	6	43	0
5	45	14	33	8
6	69	1	34	0
7	116	3	30	0

Other groups, too, echoed this preference for obtaining information orally as opposed to in writing. For instance, members of Group 7—who sought to design a headrest for a shower chair—visited a local fabric store to obtain information about which type of fabric they should use for their headrest. An employee at the fabric store, who was familiar with the properties of different fabrics, suggested marine vinyl, and this suggestion was later incorporated into the group's design. Similarly, to gain ideas for their headrest design, members of this group visited a local retirement center and viewed existing shower chairs. They interviewed workers and clients there regarding which headrest they thought was best and why. Finally, because this group was designing a headrest for one particular boy, they also interviewed this boy's family in Spanish regarding the changes they would like to see in the headrest design. This group, like the other groups, preferred to use Spanish and English to collect information verbally from a variety of sources, as opposed to obtaining similar information through written sources such as books and websites.

Group 2 represents the only exception to this tendency to favor written communication over oral communication. They sought to improve a playground in their neighborhood, and they developed and distributed Spanish and English surveys to members of the community via a website (which was linked to the city council's webpage) and via paper copies at a local library. Because they obtained many pieces of information through the written surveys, such as aspects of the park that local residents perceived to be a problem, this group had a higher incidence of obtaining information in writing as contrasted with other groups. Nonetheless, this group too indicated a preference for oral language in their interviews, even though the frequency count indicates they relied on writing. They asked a civil engineer for feedback on their playground design, and they identified his oral feedback as the most helpful source of information throughout this project. In

Eva's words: "The civil engineer I think he really helped us like on deciding how to improve the plan the design…He helped us understand ways and techniques that we could like improve the design and help it make more useful kind of like more convincing and like how we would see how much space and material we would need."

Interestingly, many groups did not obtain information in writing in Spanish, even though it was their first language. When asked why they preferred obtaining written information in English over Spanish, they gave two responses. First, they felt more comfortable with reading in English versus in Spanish because many of their academic reading experiences occurred in schools where English was the primary language. Second, they thought they were more likely to find the written resources they needed in English, versus in Spanish.

In summary, the participants (like professional engineers)[20] emphasized the importance of oral communication as a vehicle for obtaining information relevant to their projects. The participants' bilingualism was an asset in information gathering because they were able to obtain information from Spanish-speaking clients, users, and content experts—as well as English-speaking clients, users, and content experts. At times the participants named difficulty with comprehending English texts as the reason why they preferred oral communication, but at other times, they stated that they preferred oral communication because English- and Spanish-speaking experts were able to give them more tailored and useful information than they could find on websites.

Finding 2: Most groups preferred reading images over reading words on the Internet.

Although the participants preferred to collect information orally, each group also conducted Internet searches to find different types of information. However, consistent with the previous finding that they did not like to read difficult information, they tended to conduct Internet searches by looking for images rather than by looking for words. Table 4 indicates the number of times that groups read images versus texts, as observed during group meetings as an indicated in interviews about participants' individual search processes using their Internet search histories related to the project. "Google Image" was used as a search engine more often than "Google" was. (We did not notice the participants using any other search engines, such as Bing or Yahoo.) The following examples illustrate the participants' search strategies.

Members of Group One attended a school that did not have any wheelchair-accessible doors, and they had designed a basic plan for a wheelchair accessible door. To estimate costs for their door, Miguel went to Google Images and conducted a search for "handicapped doors." Several photographs of wheelchair-accessible doors appeared on his iPad screen. He tapped on an image of a door that appeared to be the most similar to the design that his group had in mind. When he tapped on the image, the website on which the image appeared was displayed on the screen. He scrolled down the website skimmed it for information on the door's costs. This example demonstrates how participants tended to use visual strategies, rather than written strategies, to find information. Miguel could have typed "cost of average handicapped door" in a regular Google search engine, but instead he preferred to use a visual strategy that would result in images rather than in words.

Table 4
Number of Times Groups Read Images and Written Texts

Group	Read Images	Read Texts
1	61	36
2	78	52
3	54	18
4	86	79
5	26	43
6	75	43
7	76	32

Members of Group Two used a similar strategy when trying to determine the cost of a playground that they wanted to design and share with a local city council. When they typed in "cost of swings" into a regular Google search engine, they soon realized that a cost of a swing was widely variable—ranging from a $40 baby swing available at their local Wal-mart, to commercial swingsets that cost $3000, excluding labor costs for installation. To better help them narrow the scope of their search, they too switched to a visual search strategy by looking for photographs of swings first, and *then* skimming websites to determine the costs of swings that looked like the ones they had in mind.

At times, the participants attributed their preference for images to the fact that written texts in English were difficult to understand. At other times, they simply attributed this preference for images to the fact that they believed images were the best source of information available for particular purposes. For instance, Group 6 sought to select a local playground at which to install their swing for children in wheelchairs. They thought that maps and aerial photographs of local playgrounds would provide them with the information they needed—such as availability of space or current material placed on the floor of the playground (e.g., rubber foam, wood chips)—as opposed to written descriptions of the playgrounds, which did not include the same precise spatial or visual information.

In summary, all groups used images as part of their search process, and they read images more frequently than they read texts. Sometimes images were used as gateways to written texts, as in the wheelchair door example, and sometimes the images were used as independent sources of information in their own right, as in the playground image example. While some participants occasionally attributed this reliance on images to the fact that they found written English difficult to understand, other participants attributed their reliance on images to the fact that images were the best source of information for particular queries.

Finding 3: Different groups collected different types of information, but no group collected information from all of the same categories that are used by professional engineers.

Oftentimes, during group meetings, members of groups would gather around an individual computer, or else they projected the screen of an individual's computer on an overhead projector so that the group could all see the designated computer screen, and so they could collectively make suggestions regarding the information gathering process. Table 5 indicates the number of times that the groups consulted each source type while they collectively conducted Internet searches during group meetings (excluding the Internet sources that they consulted individually outside of the group meetings). This table suggests that different groups varied in terms of the type of information they collectively sought. Group 2, for instance, often sought for information regarding the cost of their playground, whereas members of Group 4 focused more on technical references, such as the information about the properties of different materials they were considering for their shoe. As noted previously, the participants most often consulted websites in English rather than in Spanish.

Our analysis indicates that all groups omitted several categories of information that Bursic and Atman asserted were helpful for ensuring quality designs.[9] For instance, no group searched for "rules and regulations" related to their design. When the participants presented their designs to clients, their clients were concerned with this omission, such as when the head of the local Parks and Recreation Department asked the youth if their design met regulations specifying that swings must hold a certain weight and be a certain distance from each other. The analysis also indicated that the youth sought for categories of information not mentioned in Bursic and Atman's study, such as previous designs that helped them brainstorm ideas for their own designs.

Table 5
Participants' Information Gathering Activity on the Internet During Whole-Group Meetings

Group	Cost	Previous Designs	Technical References	DIY	Measurement	Marketing	Neighborhood Opinions
1	5	5	0	0	1	0	0
2	32	17	6	1	2	3	17
3	1	2	18	0	1	0	0
4	0	6	19	2	0	1	0
5	2	1	10	0	9	2	0
6	0	4	0	0	1	0	0
7	1	18	15	1	1	0	0

Limitations

Although this study was conducted with students who spoke English as a second language, we do not mean to imply that the participants used these search strategies *because* of this fact. Indeed, researchers have documented that many adolescents, regardless of their home language or language proficiency status, have developed strategies to avoid reading difficult texts,[19] much like the participants in this study developed several strategies (e.g., ask an adult, conduct an image search) that enabled them to avoid reading lengthy websites or other texts. At the same time, several participants in this study cited difficulty with comprehension as the reason they did not read websites, and thus this study might indicate that comprehension supports—such as explicit instruction on how to locate and interpret difficult information—might be especially beneficial for students who speak English as a second language. Thus, although we infer that students' work-around strategies for avoiding reading may have been related to their frustration with reading academic English, the design of this study does not enable us to ascertain whether students who spoke English as a first language might have felt the same discomfort.

Conclusions and Implications

This study's findings differ significantly from previous studies with primarily English-speaking high school students in lab settings. [8,10] This study indicates that the native Spanish-speaking participants used a variety of oral and visual search strategies—sometimes in their home language but commonly in English—to gather information related to their self-selected problems. Though the participants sometimes identified difficulty with understanding technical written information in English as the reason for their reliance on visual and oral strategies, they also believed that these oral and visual strategies provided more useful information and were more efficient than searching for information in writing.

This study indicates that adolescents may draw from a range of resources in their communities and on the Internet to solve problems through engineering. Engineering teachers who guide the design process might therefore be aware of these sources and incorporate them into their instruction as important sources of information. For instance, engineering teachers and students might work together to evaluate visual sources, oral sources, and written sources as they synthesize the information across these sources and identify implications for an engineering design.

This study also has implications for practitioners who espouse asset-based pedagogies, or pedagogies that view underrepresented students' languages and resources as assets to the learning process.[21] The participants' backgrounds served as assets to engineering in many ways, which we elaborate on in other publications in greater detail.[13] In the context of this study, one clear benefit of speaking Spanish was that participants could communicate with Spanish-speaking clients and create designs that were more responsive to their needs. By implication, engineering teachers might actively encourage and elicit their students' use of home languages throughout the design process, especially through encouraging their students to communicate to a range of diverse clients and stakeholders. By positioning students as experts and by explicitly acknowledging their linguistic repertoires as assets, engineering teachers may enact education that is more responsive to and affirming of linguistically diverse students.

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