Does "Affordance" Mean "Thing-inform"?: Case Studies in Seeing Engineering Meaning Differently Through the Process of Technical ASL Vocabulary Creation

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Abstract

(Note: A signed version of this abstract is available on http://aslcore.org. Although this paper has been written in English, the primary working language of this project is American Sign Language. The English paper presented here should be treated as an explanation designed for a non-signing audience.)

Engineering is a social activity where practitioners constantly use language in order to communicate. While not completely deterministic, the nature of the language we use influences how we think, communicate, and collaborate [1]. This paper draws from work on the engineering branch of ASLCore, a language creation project focused on developing vocabulary in American Sign Language (ASL) at the college level and above.

Due to the American education system's historic marginalization of signed languages and their users, there are few conceptually accurate and linguistically appropriate signs for even basic technical concepts. The attempts of ASLCore towards rectifying that situation are instructive not only in the context of including an underrepresented group in engineering education, but in making-visible the sorts of disciplinary rethinkings such a project might contribute. In other words, this is not simply about creating more signing engineers to carry out business as usual. Rather, we believe the practices of signing engineers could change how all engineers think, communicate, and collaborate, and that the activity of deliberate ASL vocabulary creation serves as one example of how this might happen. In this paper, we position sign creation as a locus for examining the construction of engineering meaning.

This paper centers on two illustrative case studies in engineering sign development: (1) the stress-strain curve and (2) affordance theory. For each case study, we begin by describing the new sign prototypes and how they fit the concept(s) they attempt to describe. We compare the new sign to previous options for signing each concept, contextualizing them as examples of the colonized/assimilated nature of Deaf Education in the United States. We then provide the backstory for the creation of our new sign prototypes, which illustrate the subjective nature of meaning-making within engineering. Finally, we examine how each new sign showcases the unique affordances a signed language provides in discussing engineering that a spoken/written language does not.

Background on ASL and Deaf engineers

American Sign Language (ASL) is the primary language used by the USA-based Deaf community, which identifies as a minority group united by linguistic and cultural similarities rather than a deficit-based disability. We use the term "Deaf" (with an uppercase D) in this paper to specifically indicate membership in this cultural group, as opposed to deaf (with a lowercase d) which indicates the state of not having typical hearing. This Deaf/deaf convention is commonly used in the Deaf community, and dates back at least as far as Carol Padden and Tom Humphries' 1988 book *Deaf in America: Voices from a Culture* [2]. If someone is not Deaf (or hard-of-hearing, or otherwise identified as having hearing loss), they are referred to as a "hearing" person.

ASL is not a makeshift system of gestures, nor is it "English on the hands." Although this was only formally recognized in the 1960s, ASL is a full language with a spatially-based grammar distinct from English [3]. However, ASL has historically not been used in advanced technical contexts due to the low number of Deaf professionals working in these fields [4]. This is in turn heavily influenced by historic educational and access-related inequities. Although a detailed timeline of Deaf education in the USA is beyond the scope of this paper, it has been heavily marked by audism and oralism, two words that refer to interlinked beliefs that hearing, speechreading, and the production of speech are superior to signed languages. These attitudes have come at the expense of the Deaf community's ability to teach, learn, and communicate in their own natural and fully accessible signed languages.

Furthermore, it was not long ago that simply having a hearing loss could bar a student from studying at an engineering program. The National Technical Institute for the Deaf (NTID), founded by Congress in 1965, was for many years one of the few places Deaf (and hard-of-hearing) students were able to receive technical degrees. Until Section 504 of the Rehabilitation Act of 1973, Public Law 94-142 of 1975, and most recently the Americans with Disabilities Act (ADA) of 1990, even academically qualified Deaf students could legally be denied accommodations or even outright admission to college programs simply because they could not hear. As a consequence, the data on the number of Deaf engineers and engineering students is sparse and unreliable, as many hid their hearing loss and "passed" as hearing in order to gain entrance to the profession.

With the enactment of laws prohibiting (but not solving) disability discrimination and mandating (but not ensuring) the provision of appropriate accommodations, openly Deaf engineers began to appear in greater numbers. Many are members of the "ADA Generation," or the first children to grow up with legally mandated access to education. The oldest of these young people are now in their late twenties and early thirties, still fairly early in their careers. Since they were often the first Deaf students in their engineering programs, their engineering educations have been conducted, with very few exceptions, entirely in spoken English.

The state of sign language usage in postsecondary engineering education

Deaf engineers and their sign language interpreters (hereafter, “interpreters” will refer to sign language interpreters in this paper) have been using sign language to communicate about technical topics for many years. However, due to Deaf engineers largely being educated in isolation from each other in English-speaking engineering classrooms, technical ASL has been slow to develop. Instead of using ASL, what is used is typically a signed form of English, sometimes called “contact sign” or “Pidgin Signed English” (PSE). This is a transliteration of English using mostly ASL vocabulary, and is the equivalent of using somewhat mangled English words in, say, German word order (ex: “I have the book past-tense-read” instead of “I have read the book”).

The widespread use of Signed English in engineering classrooms can be partially attributed to the fact that interpreters are, with rare exceptions, not engineers. While it is impossible to *interpret* a message one does not understand, it is possible to *transliterate* a message without full understanding. This is what most interpreters are forced to resort to, relying on the Deaf engineer’s subject matter expertise to piece in the rest. For example, in one case, an interpreting team was unable to figure out a phrase from context and kept signing “sounds like ‘pea soup’?” during an engineering lecture. Thankfully, the Deaf student realized the professor was referring to “p superscript” (p-sup) in a math equation.

This is not to say that interpreters are not highly trained; they must be, as the cognitive demands of interpreting are considerable. Interpreting may appear like a simple job of “just” signing what the speaker says, but doing so involves a host of strategies including but not limited to the use of vocabulary, iconic visuals, body language, space, and facial expressions. A parallel set of skills are used to convey the tone of the speaker, vocal inflection, pitch, vocal intensity, all of which influence the meaning and intent of the speaker. All these elements are spliced together in real-time to provide a rich, comprehensive, robust visual message. With engineering lectures often going faster than the average speaking pace of 125-50 words per minute, an interpreter with little to no technical background is often barely able to transliterate the material into Signed English through the use of abbreviations and initializations. However, this transliteration is what enables a Deaf engineer to use their knowledge of technical English to piece out what is being said.

Going in the reverse direction, an interpreter must accurately voice what a Deaf engineer is signing into spoken technical English. Any sound of puzzlement or strain in the interpreter’s voice from the cognitive load of interpreting can be misattributed to hesitation or misunderstanding on the part of the Deaf engineer. Unfamiliarity with technical vocabulary on the interpreter's part can also make the Deaf engineer seem less knowledgeable and competent than they really are. Oftentimes, the target is participation in a rapid-fire, high-level technical English conversation with hearing, non-signing interlocutors. Furthermore, these interlocutors (professors, colleagues, classmates, and more) are often unaware of the complex linguistic dance taking place right in front of them. Because of these and other factors, Deaf/interpreting teams tend to sign "close to the English" to reduce cognitive demands and therefore chances of error.

The history of engineering signing as Signed English rather than ASL means that engineering vocabulary is often ad-hoc and based on English homonyms. This means that they may be spelled or spoken the same way as the technical term in English, but have a completely different meaning. For instance, the sign for the technical concept of "tolerance," as in "permissible variation from a measured value," is often signed the same way as "tolerate," meaning "to put up with, to bear." Such an approach can be conceptually confusing for learners encountering this vocabulary for the first time, although it is expedient for interpreters in the heat of the task.

To change this situation requires more than simple vocabulary creation. It also requires ways to express these ideas within Deaf language and Deaf culture. This means, among other things, signs that are compatible with visual/spatial setups, that are efficient, that flow together, and do not require large amounts of expansion each time they are used. For example, in technical English, we use the word "voltage" to refer to the concept of "the electric potential difference between two points." The latter is equivalent in meaning to the former, but it is a definition rather than a vocabulary word, and takes significantly more time to use (one would typically not say "the electric potential difference…" each time they meant "voltage" in a classroom lecture). Similarly, a full definition of voltage can be signed in ASL, but this is an expansion rather than a vocabulary word, and would hardly suffice for keeping up with a rapid-fire technical lecture.

Shortcuts without conceptual linkages are not much better. To continue the example from the previous paragraph, a common way to refer to the concept of "voltage" in the context of a hurriedly transliterated technical lecture is to take the ASL handshape for the letter "V" and shake it in the air. This the semantic equivalent of telling the Deaf engineer that "they said, you know, that word that begins with the letter V." The hope is that the Deaf engineer will figure it out from context, and not confuse this with, for instance, the word "velocity," which might have been used a few seconds earlier and signed in a similar manner.

For interpreters, the lack of appropriate signed vocabularies in engineering is a major issue impeding their ability to provide a clear and confident rendition of technical conversations; for Deaf engineers, this means the messages they receive and transmit are often halting and incomplete [5]. The lack of an accurate signed vocabulary for technical topics presents severe issues for Deaf professionals in technical fields, not to mention challenges for students who are trying to learn their way into those fields. We are faced with the ironic situation of Deaf engineers who have never had the opportunity to discuss their own discipline in their own language.

History of ASLCore

The ASLCore project is a response to the need for specialized ASL vocabulary explicated in the previous section. The mission of ASLCore is to provide linguistically faithful and conceptually accurate suggestions for American Sign Language lexicon choices for various disciplines at the college level and above. Although several other projects have made important contributions to the space of technical ASL vocabulary, none fill the same niche as ASLCore's engineering branch, which is the focus of this paper. Arguably, having multiple ASL vocabulary projects is valuable in these early days of technical ASL usage, since a variety of perspectives will enable members of the community to try out and adopt the variants that feel most natural and useful to their individual circumstances.

To take a few examples of prior work in technical ASL vocabulary: DeafTEC [6] documented college-level technical signs in existing usage, which means its repository has largely captured Signed English compromises. Although this is a valuable thing to have documented, this paper has already explained why such ad-hoc signs are a temporary solution rather than a permanent one. Similarly, the ASL-STEM forum [7] crowdsourced signs for various technical concepts, but did not vet or filter them for quality. In contrast to both the above projects, ASLCore proposes new sign alternatives that convey conceptual meanings directly in ASL. More recently, the ASL Clear project [8] has also focused on developing conceptually accurate and linguistically appropriate STEM vocabulary in ASL. Although ASL Clear focuses on K-12 audiences and ASLCore is aimed at college-level and professional usage, the two projects have partnered to share, film, and host vocabulary common to both groups.

For the ASLCore engineering branch, a first round of vocabulary prototypes were developed and filmed over two weeks of work during the summer of 2018. These included the signs discussed later in this paper. Engineering was the seventh disciplinary branch developed for ASLCore. The other six branches as of this writing are Philosophy, Literature, Biology, Physics, Art, Computer Science, and Sustainability. Funding for six out of the seven content branches was provided by NTID, which funded the first branch (Philosophy) through an $13,000 USD internal Innovation Grant. Upon seeing the project's early success, NTID leadership offered the group $200,000 USD to develop four additional STEM branches before the end of 2019, with permission to use the remaining funds to develop signs in any field. The one exception to NTID funding is the

Sustainability branch, which hosts signs created by a separate project funded by the National Science Foundation (NSF INFEWS CBET-1639391). This project used the ASLCore process to develop signs as a small portion of their larger work, then worked with the ASLCore team to film and publish those signs on the internet.

Each branch has its own all-Deaf team for sign creation. A typical team includes one (or in rare cases, two) Deaf content experts, typically with advanced degrees and college teaching experience in the relevant discipline. It also includes several (typically four) Deaf language masters for whom ASL itself is their primary disciplinary specialty. Language masters typically have backgrounds in translation, interpreting, linguistics (of signed languages), and/or ASL literature, teaching and performance. As of this writing, ASLCore has employed nine content experts, twenty language masters, six interpreter consultants, and five student workers serving as gophers to feed and water the team.

As part of the ASLCore sign prototype creation process, the Deaf content experts teach their field to the Deaf language masters, and the language masters in turn generate sign ideas that the content experts verify for conceptual accuracy. The group creates both signs and expansion videos of how and in what circumstances to use which sign for what concept. For instance, for signal processing, the sign for “frequency” in the time domain is different for the sign for “frequency” in the frequency domain, so example usages are provided for both. Hearing interpreter consultants are on hand to provide insight as to how hearing instructors typically use the words in English-language lectures, but the process is centered around language creation by Deaf people. All the vocabulary is chosen, developed, and modeled by Deaf people who are fluent signers of ASL.

Thus far, the ASLCore team has focused on creating both product (sign vocabulary prototypes for various disciplinary concepts) and process (a methodology for developing signed vocabulary prototypes). Both are equally important, and process iteration has led to multiple key insights. For instance, it was thought early on that having multiple content experts for a branch would allow for the team to have even more insight into the discipline for sign creation. It soon became evident that having multiple content experts could lead to unproductive conflicts if the experts became locked in disagreement. Subsequent sign creation teams were restricted to one content expert, or perhaps two if they were already familiar with their own collaborative dynamics.

Similarly, it was initially assumed that language masters with a background in the branch's target discipline would be beneficial for the creation of new signs. On the contrary, it turned out that having no background in the field allowed language masters to create signs unfettered by prior vocabulary and assumptions. This, in turn, led to what the Deaf team members felt were clearer and more conceptually illustrative signs. The process of developing a concept's sign paralleled the process of the language masters developing their understanding of that concept, as demonstrated by the case study on affordance theory featured later in this paper. Subsequently, ASLCore embraced the notion of language masters with no background in the target branch's field, which allowed the project freedom to choose from a wider variety of collaborators.

The following two sections will employ illustrative case studies of what vocabulary creation looks like using ASLCore's process. As the authors of this paper were involved in the process of vocabulary creation, the case studies and the discussion that follow will be written in first person plural ("we"). Note that this paper does not seek to measure the effectiveness of these signs or validate them within the Deaf community, which is work that may be taken up in future studies. Instead, each illustrative case study focuses on qualitatively unpacking the anatomy and history of a small number of signs in detail. The goal is to familiarize readers, who may be new to signed languages and Deaf cultures, with the sorts of complexities inherent in the translation and sign creation process. As noted in the abstract, each case study will consist of a description of the new sign, comparison with previous sign options (if they exist), a narration of the sign creation process, and some affordances of signed languages that the case makes visible. Note that while images have been provided to illustrate some of the signs in the case studies, the video links below each image provide a fuller depiction and should be viewed when possible.

Case study 1: stress and strain

In engineering, the term "stress" is used to describe a load applied to a continuous piece of material (ex: pushing down on a metal bar), and the term "strain" describes the deformation of that material under the load (ex: the metal bar bending). Both terms are often used to foreground the properties of the material itself, rather than the particular size or shape of the item that happens to be made out of that material.

The relationship between stress and strain for a given material can be plotted on a stress-strain curve, and is determined by what happens to it under load, on a molecular level. The new sign prototypes make this explicit by building on one version of a sign for "molecule" (Fig. 1, below). This sign for "molecule" is produced with two clawed hands moved together, each representing an atom within the molecule.

Fig. 1. One ASL sign for the concept of a chemical molecule.
Video: https://aslcore.org/physics/entries/?id=molecule

The noun form of "stress," then, is simply those atoms being forced together, depicting the load at a molecular level (Fig. 2, below). Note the facial expressions, which are part of the sign; these are sometimes called "non-manual markers" or "mouth morphemes" in signed linguistics parlance. Here, the "clenched teeth" mouth morpheme indicates effort or struggle. To represent the verb form of "stress" (as in the phrase "to stress the sample"), motion is added to the sign (Fig. 3, below).

Fig. 2. One ASL sign for the concept of mechanical stress (noun).
Video: https://aslcore.org/engineering/entries/?id=stress

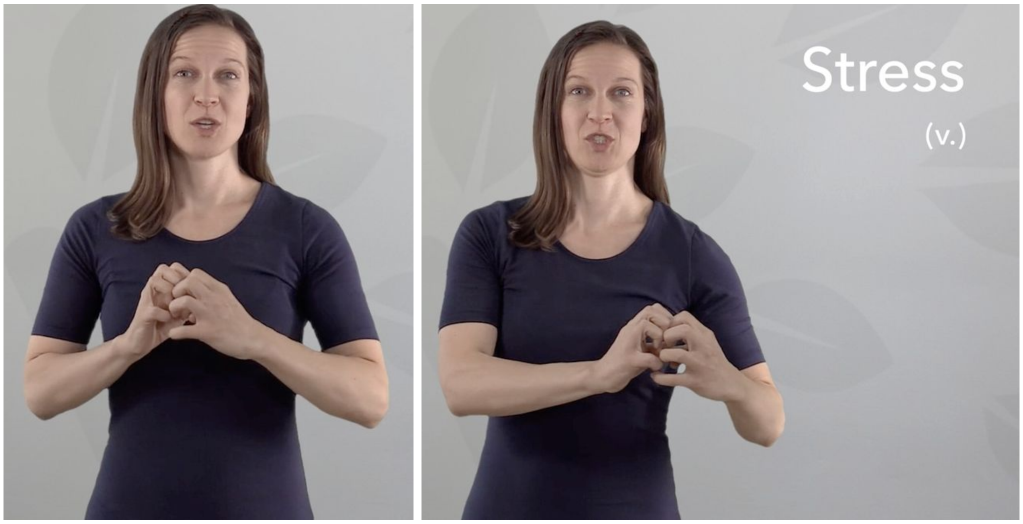

Fig. 3 . One ASL sign for the concept of mechanical stress (verb).
Video: https://aslcore.org/engineering/entries/?id=stress

The new prototypes for "strain" are similarly based on the sign for "molecule." The same handshapes depicting atoms are used, but this time sheared away from each other to show the resulting deformation at a molecular level (Fig. 4, below).

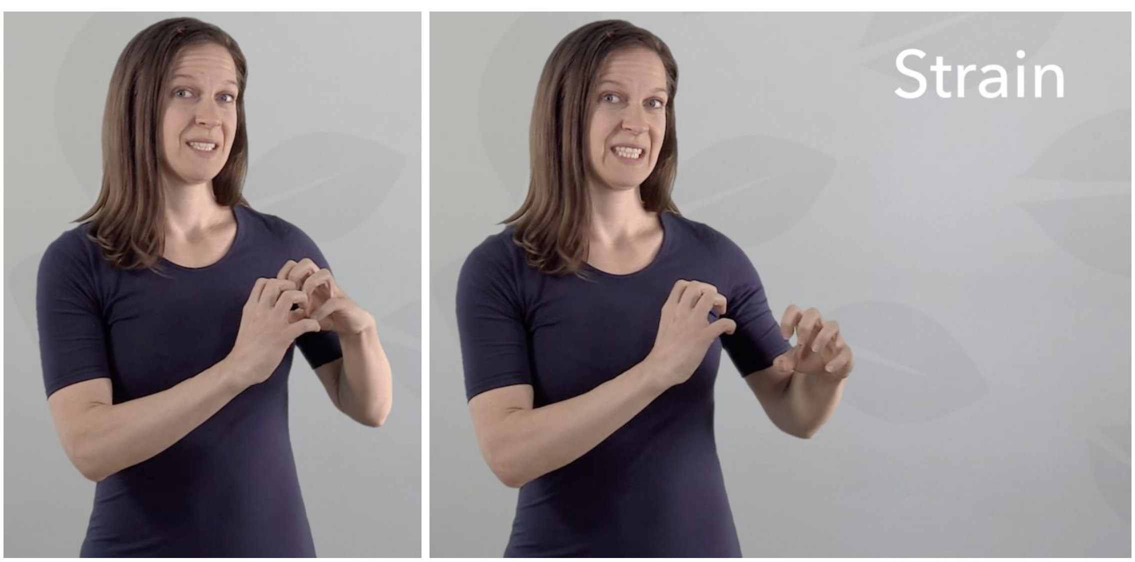

Fig 4. One ASL sign for the concept of mechanical strain.
Video: https://aslcore.org/engineering/entries/?id=strain

The new prototype signs for "stress" and "strain" are deliberately related to each other, yet distinct; they clearly represent different concepts. Prior to these new signs, "stress" and "strain" were often translated using the same ASL sign, which was also used for "pressure." (Fig. 5, below) depicts this sign; the dominant hand is pushed, palm-down, over the nondominant fist. Since “pressure” is a more commonly used word in English than either “stress” or “strain,” the English word “pressure” is usually used to refer to that sign (or in linguistics parlance, used to “gloss” it).

Fig 5. One ASL sign for the concept of pressure, as in force over unit area.
Video: https://aslcore.org/engineering/entries/?id=pressure

In non-technical contexts, using the same sign for all three English words can occasionally be appropriate. The English words “stress” and “strain” can refer to similar emotional and psychological states; one can be “stressed out,” have something “really put a strain on you,” or be “under a lot of pressure.” However, in an engineering education context, using the same sign for all three terms makes it difficult to distinguish between the three concepts, or even to realize there are three separate concepts in the first place. An English-language analogy might be the sentence “There are many different kinds of bread; for instance, bread, bread, and bread” - as opposed to “There are many different kinds of bread; for instance, challah, focaccia, and baguettes.” Seeing the “same word” multiple times in a row can be nonsensical and baffling.

The usual interpreting solution in this situation is to form one base sign with your hands, then use silent mouthing and lipreading to differentiate between specific English words. This is commonly done, for instance, with “battery” vs. “electric” vs. “circuit.” However, lipreading is an unreliable and cognitively draining solution that assumes that the receiver already knows the

English word in question. Furthermore, “stress” and “strain” begin with the same consonant patterns, and can easily look similar on the mouth, meaning that lipreading would not be a good way to differentiate between them.

To alleviate this situation, new signs had to be created. The sign glossed “pressure” portrays a force pushing down on a surface, so it was still a good conceptual fit for the formal technical concept of pressure (force over unit area). This left “stress” and “strain” as concepts that needed new engineering signs. Our team did discuss simply using the engineering sign for “pressure” as the engineering sign for “stress,” since the two use the same unit (the pascal). However, we decided it would be clearer to have separate signs to distinguish between “stress” and “pressure”; after all, it was the stress-strain curve, not the pressure-strain curve. In the interim, we agreed to use “pressure” as a placeholder sign for “stress” so that we could continue discussing the stress-strain curve in sign, without switching to spoken English.

Since Deaf engineering students are typically already familiar with non-technical English, we wanted our new signs for “stress” and “strain” to emphasize that these words had different meanings when used technically rather than colloquially. A steel bar is presumably not psychologically affected by the forces applied to it. Our first breakthrough came when we started discussing what deformation looked like at the molecular level, which led to the sign prototype variant for “strain” shown at the start of this case study. Similarly, other signs related to stress and strain depict the visual characteristics of material behavior. For instance, see the signs for ductile failure (Fig. 6) and brittle failure (Fig. 7) below. The characteristics of the fracture surfaces are visible in both the handshape and facial expression (mouth morpheme); a ductile material necks and pulls apart, whereas a brittle material snaps off at a flat surface.

Figs. 6 and 7. ASL sign options for the concepts of ductile and brittle fracture, respectively. Videos: https://aslcore.org/engineering/entries/?id=ductile , https://aslcore.org/engineering/entries/?id=brittle

The “aha” moment linking the sign for “stress” to the sign for “strain” came towards the end. At some point, we realized that nearly all our other signs for points on the stress-strain curve were depicting what happened on the molecular level, using the handshape denoting spatial relationships between atoms. One of our criteria for creating good signs is that they need to link and flow together in ways that make them usable for visually discussing technical topics. Among other things, this means that two signs that will frequently appear together must be easy and smooth to sign together, both physically (transitions between handshapes should be smooth and efficient) and in the ways we use them to visually represent related concepts.

Consequently, it felt awkward to use molecular-level handshapes for the stress-strain curve, then abruptly switch to signing “pressure” for the concept of “stress.” This was confusing, similar to the effect of counting “one, two, tres, four” (counting in English and switching to Spanish only for the number “three”). Instead, we revised the sign for “stress” to also depict the concept at the molecular level, which resulted in the sign prototypes presented in Figs. 2 and 3.

In addition to molecular-level depictions of points on the stress-strain curve, we created a supplementary set of alternatives for most points depicting how one would see them with the naked eye (the missing alternatives would have been physically impossible to sign, given the range of motion of typical human hands). As one example, both naked-eye and molecular magnification level variants for elastic deformation are shown in the image sequences below. The former variant (Fig. 8) shows a sample being bent by a clamp, which is what one would see with the naked eye, and is useful for depicting a lab experiment setup. The latter variant (Fig. 9) shows molecular bonds stretching, and is useful for depicting the internal state of the material itself. Regardless of their scale of magnification, both sign variants for “elastic deformation” show an object bending or stretching, then returning to its original form. Note that to sign the concept of “plastic deformation,” the second position (middle frame) of each sign would be held, and the third position/frame eliminated, which represents the object being taken past the point where it ceases to spring back to its original form.

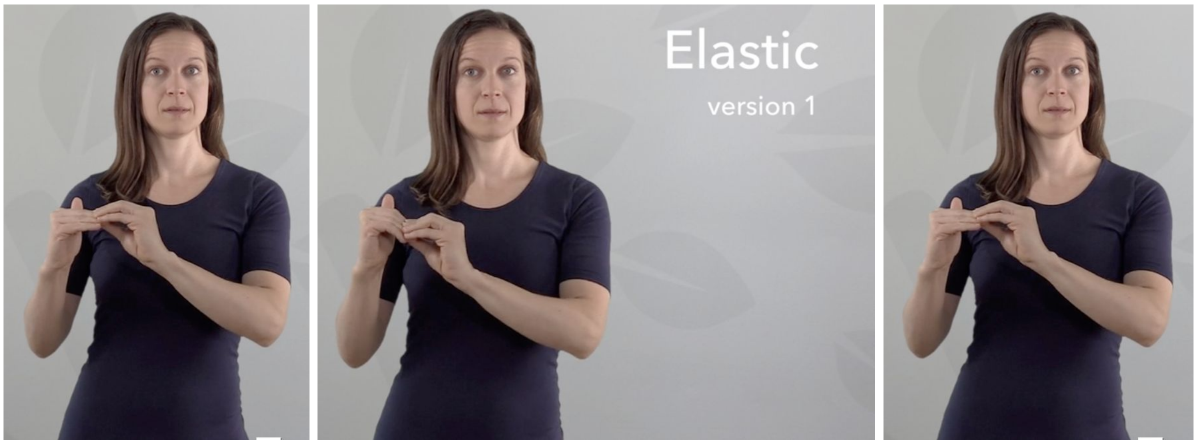

Fig. 8. One ASL sign for the concept of elastic deformation, signed to resemble what one would see with the naked eye.
Video: https://aslcore.org/engineering/entries/?id=elastic

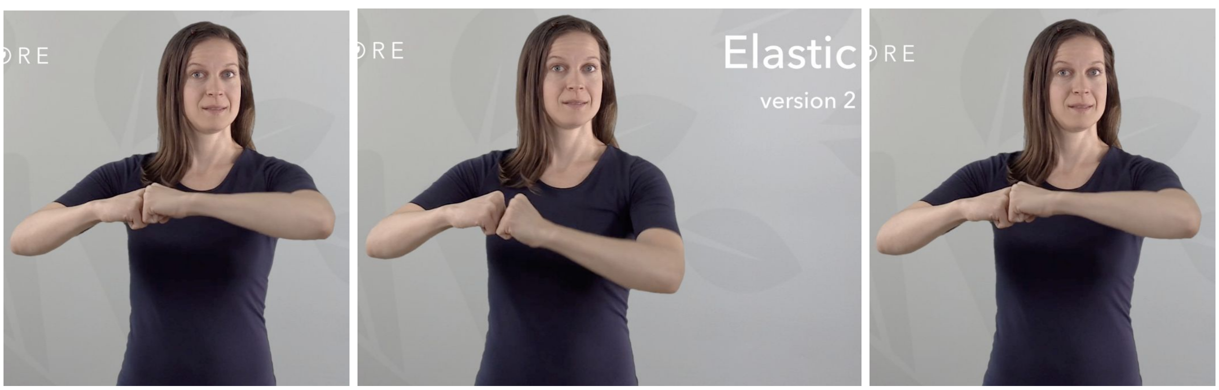

Fig. 9. One ASL sign for the concept of elastic deformation, signed to resemble what one would see at the molecular level with a powerful microscope.
Video: https://aslcore.org/engineering/entries/?id=elastic

With the new sign prototypes for the stress-strain curve, signers can choose and move between different levels of magnification in their explanations. This practice is sometimes referred to as “cinematic ASL” [9], and is similar to how a movie camera might zoom in and out and cut between shots to show relationships between scene elements. Cinematic techniques are an affordance unique to visual-spatial languages; to approximate the same effect in a non-signed language such as English takes a great deal more effort and space.

Case study 2: affordance

In engineering design, the word “affordance” is used to discuss what an object “affords” - that is, what it hints at or allows regarding its own intended usage. For instance, a chair affords sitting. A doorknob affords turning and pulling; a door plate affords pushing. Unlike some other technical terms, there is no universalized set meaning for what, precisely, “affordance” and “to afford” mean in English. One reason we are proud of our signs for “affordance” and “afford” is that they feel (at least to the authors) as if they capture both the shared essence and the inherent ambiguity of the concept represented in that discourse, without attempting to come down on one side or another of the definition debate.

Our sign for “to afford” is rooted in an existing ASL sign that is often translated into English as “to inform” or “to let (another person) know.” As shown below (Fig. 10), this particular sign begins with closed hands at the source of the information (here, the signer’s forehead, where knowledge is usually depicted as residing). The signer then opens their hands towards the recipient of the information. When signed towards oneself, it means “inform me” or “let me know.” When signed towards another person, it means “inform them” or “tell them.” This sign can also be swept out to encompass providing information to multiple people in a group. In other words, this sign is a directional verb; the motion path of the sign indicates who is informing whom [10].

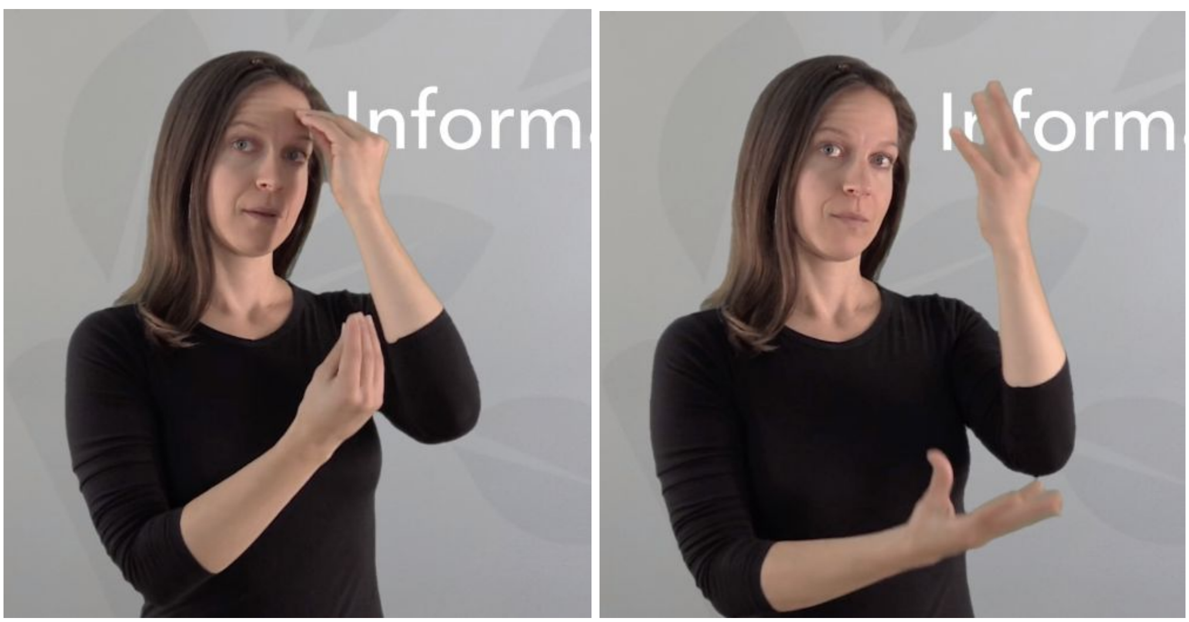

Fig. 10. An ASL sign often translated into English as “to inform” or “to let know.” Video: https://aslcore.org/computerscience/entries/?id=information-(theory) (Note: full video is information (n, theory), not inform (v), but the root sign is the same.)

Our sign for “to afford” uses the same motion and handshape of “to inform.” Instead of originating from a person, it originates from a thing. In (Fig. 11) below, the thing is represented by an invisible object held in the signer’s other hand, but it could just as well be signed in reference to an actual physical object in the room.

Fig. 11. One ASL sign for the verb "to afford," as in affordance theory.
Videos: https://aslcore.org/engineering/entries/?id=affordance ,
https://aslcore.org/engineering/entries/?id=afford

Translating only from the sign (and not any existing English definitions of the word "afford"), this sign in ASL denotes the object "letting us know" about itself, about how we might use it, and so forth. For an object to afford something is for it to be informing us via how it exists as an object, as opposed to, for instance, having separate documentation telling us how we ought to use it. A fluent user of ASL should be able to pick up on these conceptual nuances from the sign alone, even if they are unfamiliar with the term in English. Once the concept is understood, the sign can then be linked to the corresponding English word.

To create the noun form of the word ("affordance"), one simply signs a possessive marker towards the object at the beginning. A possessive marker is used to denote concepts such as yours/mine/ours; adding a possessive marker to "I/me" changes it to "my/mine," and so forth. In the case of "affordance," the possessive marker assigns the affordances as belonging to the object, and also grammatically changes it from a verb to a noun. Again, roughly speaking — the concept embedded in the sign is that of the things that the object tells us about itself. A expansion might go as follows: "See that object? See how it tells us things about itself? Those things it tells us — they are affordances."

Prior to creating these new signs, we were aware that some signers simply used the ASL sign for "permitting/allowing," or the sign for "all right." However, we felt "affordance" had a distinct meaning that neither of those signs covered. For instance, the ASL sign for “permitting/allowing” implies permission, whereas an object can afford something that one does not have permission to do. Similarly, the ASL sign for “all right” can imply social acceptability, even approval, whereas an object could clearly afford something socially inappropriate; ex: a weapon affords harming people, but this does not making doing so “all right” in most situations. The sign for “can/possible/able” was considered as another alternative, and similarly rejected. While it is possible to put a chair on one’s head, a chair does not afford head-covering in the same way that, for instance, a hat does.

The other alternatives involved making explicit references to the English word rather than creating a sign with meaning associations in ASL. We could fingerspell out each individual letter of the English word, but this would be painfully slow and give no hint as to the meaning. Short fingerspelled words can and do turn into lexicalized signs [11], where the flow of the fingers spelling out the word becomes a sign in and of itself (as in the sign for “ok,” which consist of the letters ‘o’ and ‘k’ in one smooth transition). However, the word “affordance” is far too long to lexicalize.

Sometimes lexicalizations are made by abbreviating a word, but there are limits to this approach. In the case of “affordance,” there is no obvious smooth and readable contraction (“aff”? “affdc”?). A word’s abbreviation may also already be in use; for instance, “SC” cannot be used for “semiconductor” because it already means “South Carolina,” and “BC” cannot be used for “bypass capacitor” because it already means “birth control.” Context can provide hints for disambiguation, but at the expense of additional cognitive load. If overused, lexicalization and abbreviation turn sentences into alphabet soup (“what kind of SC is used to manufacture that BC”?).

We could also refer to the phonetics of the word in spoken English, signing “afford” as in “afford the cost,” then “dance” as in “dance to the music.” This was not only conceptually inaccurate, it was downright conceptually misleading. Both techniques are, sadly, commonplace in fast-paced interpreting or signing contexts where precision is needed and no better alternative exists. Breaking the English word into phonetic components is what leads to renderings such as “tiny administrative person” for “microcontroller” (micro-controll-er).

Since none of these options were acceptable to us, we set out to create a new sign. We began with the content expert attempting to explain the conflicting formal definitions of “affordance” to the rest of the team, since the concept has no obvious platonic visual form. Our marathon multi-hour discussion led us down philosophical rabbit holes and pushed our understanding of the topic, the terms, their usage, and their interconnections. Our content expert had written papers using affordance theory, and commented that they had never thought so hard about what it means for an object to afford something, or what an affordance was, or was not.

Was an affordance like a feature? Did something need to be a product in order to afford things? Did it need to be a final product, or could a design or prototype or an object that was not designed by humans also have affordances? (Yes; a chair affords sitting, but so does a fallen tree stump in the woods.) How was the notion of affordance related to our earlier discussion of the functions of a product? (Later, we would discuss how a software function in the context of computer programming was both related to and distinct from this notion of the functions of a product.)

At some point, someone signed "so, it's what the thing tells you about itself?" and there was an electric moment in the room. "Yes, that! It's what the thing tells you about — how you can use it, what it's for…" And so, with several grammatical and production tweaks, our signed prototypes for affordance theory was born.

The signs for "affordance" and "to afford" reveal (or rather, afford) exploring aspects of affordance theory that may be less obvious in English. For instance, when these signs were shown to a hearing non-signer who uses affordance theory in their research, they began to use the signs as tools with which to think about the theory. "Would it," they asked, "be signed differently if I talked about what an object affords me, as opposed to what an object affords someone else?" The answer is yes: you simply change the directionality of the sign. This corresponds to the notion that an object's affordances are relative to whoever might be using it; a car seat might afford sitting for an infant, but not a grown adult.

Just as prefixes and suffixes (whether from Greek or Latin etymology) morph the meanings of English words for meaning, nuance, and clarity, creating a system of new base signs in ASL provides the armature for further sign creations to express a myriad of further vocabulary. How does "code" relate to "function" and "argument", how do those in turn relate to "recursion"? How does our representation of a "(code) repository" then inform our representation of actions involving a repository - cloning, merging, forking? All of these ideas will formulate modulations of the foundational sign, creating a nexus, or "family tree" of related vocabulary that is consistent and cohesive, and pushing those who play with such signs towards deeper understandings of the conceptual connections involved.

Discussion

The preceding two case studies of sign creation serve as glimpses into the sorts of meaning-making operations that the process of translation into a visual/spatial language can, quite literally, make visible. Engineering has been characterized as a high-consensus field [12, 13, 14], which is typically accompanied by highly standardized vocabulary sets whose origins may have by now become habitual to practitioners. Translation into ASL involves not only translation into a different language, but into a different modality (spoken/written to signed), which can serve as a stimulus for engineer-translators to become more aware of the origin stories behind the vocabularies they may take for granted.

ASLCore also has the potential to tie into existing research such as the development of spatial visualization skills in engineering education [15,16] and the use of embodied cognition in STEM learning [17]. Several faculty at NTID have begun experimenting with this in their classrooms, although their efforts remain unpublished as of this writing. For instance, one faculty member introduced key vocabulary simultaneously in ASL and English to an electronics technology class of hearing, non-signing students in order to give them a tactile/kinesthetic option for grasping the concept. Another faculty member at the same institution has recently begun research in chemistry education whereby a particular organic chemical process is being taught to other professors in ASL so they may in turn model it to their students. The goal is similarly to create a synergy of tactile and cognitive “aha!” moments and a more robust crystallization of understanding.

In essence, we ask: instead of viewing ASL merely as an accommodation to give Deaf engineers access to conversations in their field, how might we see it instead as a gift that this community brings to the field itself? This is in keeping with the concept of “Deaf Gain,” [18] an inversion of the negative framing of “hearing loss.” Deaf Gain presents Deaf people and their signed languages not as tragically disabled, but as profound contributors to linguistic and perceptual/expressive diversity in our world. We feel strongly that this project opens a door for all, not only to the actual academic content of the signs, but to another way of thinking, visualizing, and embodying knowledge. This whole enterprise seeks to create both a literal and figurative "corpus of knowledge."

The future of ASLCore

Our initial round of funding allowed us to pilot our process for prototype sign vocabulary creation in eight subject areas, which we call "branches." This summer concludes our current round of funding; we will be doing vocabulary development on a new Organic Chemistry branch, as well as wrapping up first-round sign development for the Biology and Physics branches. The engineering branch is considered to have completed its first round of sign vocabulary development.

On the engineering branch alone, there are 229 signs, 15 expansion videos (potentiometer, circuit test setup, control types, system/subsystem setup, pins and pads, accelerometer, five examples of how to sign circuit diagrams, and four examples of different pole/throw switch setups), along with 3 etymology videos (one for the story behind the creation of signs for energy/work/power, one for resistor/resistance/voltage, and one for sensor). Between June 2018 and March 2019 (10 months), the website registered 33,161 hits across all site branches, with 2,103 of those in the engineering branch specifically (7% of total site visits). Considering that engineering is tied with computing for the newest branch of the website and that we have done almost no advertising, this is significant.

Now that this process has been tested and demonstrated to work for a large variety of fields, one future goal is to document the sign prototype creation methodology in both English and ASL on the project website so that other groups can use it. We are happy to collaborate with other teams that wish to use this methodology to develop vocabulary in their own domains of interest. We are also working through the process of explicitly open-licensing the content on the website, which currently contains no instructions for those who might wish to reuse our work. This will make use and reuse permissions clearer for future efforts.

Through the process of developing these signs, using them for our own work, and dialoguing with other Deaf technology professionals, we have come to realize that further work needs to be done to not only develop more new signs, but to refine, validate, and contextualize them. Since the original project leaders are stepping down due to retirement and/or other responsibilities, we are currently discussing how to transition leadership, with a goal of having the project eventually be entirely Deaf-led. Our progress is largely constrained by funding restrictions as well as finding time during the summer for contributors — most on busy academic and professional schedules — to meet for one or more weeks at a time.

We are also discussing how to structure future phases of project development to include research approaches that can document, validate, and disseminate this work even further. This has been challenging but also educational and rewarding, since the original leadership team's expertise lies in ASL interpreting rather than research. Within the engineering and computer science branches, the branch team has started to informally gather feedback from Deaf (and hard-of-hearing) students and working engineers on how these terms have been or could be useful in their contexts. These early informal discussions have already led to a few revised signs and expansions. There has also been interest from Deaf/signing communities from other countries, which raises the question of how signed technical terminology will take hold in international contexts; will other countries create their own terms that fit their own unique signed languages, or adapt/adopt our highly American-specific versions? These and other questions remain to be pursued.

We would like to continue this project and pursue validation, improvement, and dissemination of of existing signs within the Deaf community. There is also a great need for further vocabulary development, which we believe needs to be identified and driven by Deaf engineers and students. Beyond the Deaf community, we also feel there is great merit to providing the hearing engineering education community an opportunity to peek into our work, which was part of the impetus behind writing this paper. We look forward to future opportunities to share our language and culture with others as a catalyst to rethinking how our field can conceptualize and teach these concepts.

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References

[1] L.M. Ahearn, *Living Language: An Introduction to Linguistic Anthropology*, Malden, MA: Wiley, 2012.

[2] C. Padden and T. Humphries, Deaf in America. Cambridge, Mass.: Harvard University Press, 1988.

[3] W. Stokoe, Sign language structure: an outline of the visual communication systems of the American Deaf. Buffalo, NY: University of Buffalo, 1960.

[4] P. Hauser, K. Finch and A. Hauser, *Deaf Professionals and Designated Interpreters*. Washington: Gallaudet University Press, 2009.

[5] C. Beaton and A. Hauser. "Timeliness, Technology, Terminology, and Tact: Challenging Dynamics in Information Technology Environments," in *Deaf Professionals and Designated Interpreters*, P. Hauser, K. Finch and A. Hauser, Eds. Washington DC: Gallaudet University Press, 2009, pp. 210-224.

[6] "Stem Sign Video Dictionary," DeafTEC, n.d. [Online]. Available: http://deaftec.org/stem-sign-video-dictionary. [Accessed: 29-Mar-2019].

[7] "ASL-STEM Forum," ASL-STEM, 2009. [Online]. Available: https://aslstem.cs.washington.edu/. [Accessed: 29-Mar-2019].

[8] J. Reis, R. Hoffmeister, and Y. Laurence. "ASL Clear," ASL Clear, 2016. [Online]. Available: http://aslclear.org. [Accessed: 29-Mar-2019].

[9] "Cinematic devices in sign language", Handspeak.com, 2019. [Online]. Available: https://www.handspeak.com/learn/index.php?id=13. [Accessed: 23-Mar-2019].

[10] C. Padden. "The Relation Between Space and Grammar in ASL Verb Morphology," in *Sign Language Research: Theoretical Issues*, C. Lucas, Ed. Washington, DC: Gallaudet University Press, 1990, pp. 118-132.

[11] K.J. Mulrooney. "Variation in ASL Fingerspelling," in *Turn-taking, Fingerspelling and Contact in Signed Languages*, C Lucas, Ed. Washington, DC: Gallaudet University Press, 2002, pp. 3-26.

[12] A. Biglan. "The Characteristics of Subject Matter in Different Academic Areas," *Journal of Applied Psychology*, Vol. 57, No. 3, pp. 195–203, 1973.

[13] M. Borrego. "Conceptual Difficulties Experienced by Trained Engineers Learning Educational Research Methods," *Journal of Engineering Education*, Vol. 96, No. 2, pp. 91-102, 2007.

[14] J.B. Lodahl and G. Gordon. "The Structure of Scientific Fields and the Functioning of University Graduate Departments," *American Sociological Review*, Vol. 37, No. 1, pp. 57–72, 1972.

[15] S. Sorby and B. Baartmans, "The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students",

Journal of Engineering Education, vol. 89, no. 3, pp. 301-307, 2000. Available: 10.1002/j.2168-9830.2000.tb00529.x.
[16] S. Hsi, M. Linn and J. Bell, "The Role of Spatial Reasoning in Engineering and the Design of Spatial Instruction", Journal of Engineering Education, vol. 86, no. 2, pp. 151-158, 1997. Available: 10.1002/j.2168-9830.1997.tb00278.x.
[17] S. Weisberg and N. Newcombe, "Embodied cognition and STEM learning: overview of a topical collection in CR:PI", Cognitive Research: Principles and Implications, vol. 2, no. 1, 2017. Available: 10.1186/s41235-017-0071-6 [Accessed 23 March 2019]
[18] H.D Bauman and J.J. Murray. “Deaf Studies in the 21st Century: "Deaf gain" and the Future of Human Diversity,” in *The Oxford Handbook of Deaf Studies, Language, and Education*, M. Marschark, P. Spencer, P. Nathan, Eds. USA: Oxford University Press, 2010, pp. 210-225.