”Not seeing me as an engineer is, to me, not seeing me.”: Problem Solving as an Avenue to Engineering Identity Formation

Danielle Usinski, University at Buffalo, The State University of New York

Danielle Usinski is a graduate research assistant in the Department of Engineering Education at the University at Buffalo. She is currently pursuing her Master of Science in Biomedical Engineering and is set to graduate in May 2025.

Alyndra Plagge, Trinity University

Alyndra Plagge is an undergraduate Psychology student at Trinity University. She is majoring in Psychology and minoring in Education and set to graduate in May 2025. After graduation, she plans to pursue her master’s degree in clinical counseling.

Dr. Emma Treadway, Trinity University

Emma Treadway received the B.S. degree in Engineering Science from Trinity University in 2011, and her M.S.E. and Ph.D. degrees in Mechanical Engineering from the University of Michigan, Ann Arbor in 2017 and 2019, respectively. She is an Assistant Professor in the Department of Engineering Science at Trinity University in San Antonio, Texas. Her research interests include haptics and the role of affect in engineering education.

Dr. Jessica Swenson, University at Buffalo, The State University of New York

Jessica Swenson is an Assistant Professor at the University at Buffalo. She was awarded her doctorate and masters from Tufts University in mechanical engineering and STEM education respectively, and completed postdoctoral work at the University of Michigan. Her research examines emotions within engineering problem solving and the student experience, engineering judgment, and elementary school teachers learning to teach engineering.

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Abstract

This empirical research paper examines how one student strengthens their engineering identity by framing problem-solving as a core aspect of their identity in an in-depth n=1 case study. We propose that problem-solving is more than just a process, and can also become a distinct personal identity outside of traditional engineering contexts. After analyzing interviews with Projector Man, we found their experience with problem-solving in theater and through life challenges aided in the development of their strong engineering identity by reinforcing their engineering interest, performance, and self-recognition, which compensates for weaker conventional identity markers. Our findings highlight the potential of incorporating strategies in first-year engineering curriculum to help students connect non-engineering experiences to their engineering identities.

Keywords: Engineering identity, identity, problem-solving, self-recognition

Introduction

As the field of engineering continues to grow, universities are focused on improving retention rates of students pursuing engineering degrees [1]. Existing quantitative research has provided generalized correlations between high grades, academic success, and retention in engineering programs [1, 2]. These serve as a good starting point for analyzing student retention, however, with an increasing emphasis on student engineering identity, it is important to also collect qualitative data that can provide more specific reasoning as to why certain students drop their engineering majors and others persist and achieve the degree [1, 3].

Numerous studies have indicated that a strong sense of engineering identity correlates with eventual success in the field after graduation [4-6]. Some universities have implemented intervention strategies by gearing curriculum and department culture towards supporting students' development of their individual engineering identities with this known promise of student success [6]. Some major curricular changes surround the emphasis on design problems used throughout engineering courses that inherently help students to feel more like an engineer after completing the project [7]. Because the act of problem-solving correlates with the direct development of all three of Godwin's facets of engineering identity, providing more opportunity for students to solve real-world problems correlates to retention [8] and success in the field [9].

Studies have also investigated how outside identities influence one's engineering identity. Most of these studies focus on identities surrounding underrepresented populations including but not limited to gender, race, ethnicity, and socioeconomic class [10-12]. While these studies are beneficial to building a more inclusive environment, they fail to look at interest-based identities relating to things like music, sports, and hobbies that could also influence a student's engineering experience. With a lack of research surrounding outside identities based on interests, it is important to look for other existing identities that could also impact a student's engineering identity.

Our study focuses on one particular student who exhibits low performance and negative

recognition from others that prior research would define as indicators of a weak engineering identity [5, 8, 13], yet continues to pursue engineering coursework each semester. Projector Man possesses a strong outside and interest-based identity as a "problem-solver" that allows them to experience high self-recognition through non-engineering avenues. This unique outside identity caused our research team to ask:

> *RQ1: How is a problem-solver identity distinct from an engineering identity?*
>
> *RQ2: How does problem-solving outside of typical engineering coursework and activities influence engineering identity?*

With this N=1 case study analysis of Projector Man, we hope to bring awareness towards outside identities that can influence one's engineering identity. We argue that engineering identity can be developed through outside identity formation in non-engineering contexts. With these results, we hope that instructors introduce intervention strategies into first-year engineering courses that guide students to recognize outside of engineering identities and activities as beneficial to engineering.

Background

Engineering Identity Framework

Many different definitions of identity have arisen within identity literature such as "a certain kind of person" [14, p.99], or who we think we must be to engage in a specific career [15]. Identity is composed of different role identities, or meanings attached to a social or cultural role [8], such as gender or person of color. In this paper, we discuss outside identities and engineering identity. Engineering identity is a specific role identity that students create through their experiences in engineering [8]. Outside identities is used as an umbrella term to refer to any role- or interest-based identity that is not specifically an engineering identity.

We draw upon prior identity research by Carlone and Johnson [5], Hazari [13], and Godwin [8] to generate and define an engineering identity framework composed of four facets: performance, competence, interest, and recognition. In defining performance and competence, it is important for us to differentiate what is able to be outwardly expressed and what is internalized as those can often differ. We define performance as the ability or belief in ability to outwardly express skills and practices relevant to engineering and competence as the ability or belief in ability to understand engineering concepts. The ability to practice and understand engineering concepts influences a student's ability to recognize themself as an engineer [8]. Interest is defined as personal desire or curiosity to learn, think about, or participate in engineering related activities. Interest is connected to motivation. It plays an important role in students' desire to even pursue the degree and consider themself an engineer [8]. Finally, recognition is defined as recognition by oneself or by others as an engineering person, as interpreted by the individual. Recognition has to come from a meaningful other, as interpreted by the individual, for it to be of importance for identity. Recognition from others has the ability to shape self recognition. Students who receive no recognition from peers and professors have weaker engineering identities and experience lower levels of belonging [16].

Problem-solving in Engineering

Current literature about problem-solving does not yet distinguish a problem-solver identity, however it provides context surrounding the act of problem-solving [17], how students value the skill of problem-solving [18], and the influence successful problem-solving experiences have on the development of engineering identity [19].

The act of solving a problem can be done through many different avenues and is often characterized by a list of steps [17, 20]. An accepted and generalized methodology that combines the many methods of creative problem-solving involves, "A) Planning your approach, B) Defining the correct problem/understanding the challenge, C) Generate Ideas/Alternatives – Brainstorm, D) Decide course of action/Preparing for action/Carry through/Implement, E) Acceptance and Evaluation," [17]. It is also important to know that there is a common belief and value among engineering students that the skill of problem-solving is necessary for future career success [21]. Students apply different combinations of the problem-solving steps based on the type of problem given, prior knowledge before completing the problem, and beliefs about the usefulness of problem-solving in future careers [18]. This makes it difficult to tailor curriculum to one specific problem-solving methodology that would benefit every student in the same way [17, 18]. Some studies on problem-solving have examined its impact on the development of outside identities. The act of problem-solving allows for the emergence of outside identities related to personality traits including "organizer," "strategizer," and, "sense-maker," that help students better understand their placement within engineering programs [22, 23]. Additionally, successfully completing simulated real-world engineering problems has shown links to strong showings of Godwin's performance and competence engineering identity markers [19].

We call upon prior literature to further develop problem-solving as not only a skill of engineers or an activity to develop engineering identity, but as a distinct outside identity that has the ability to enhance one's overall engineering identity when acknowledged and celebrated.

Methods

N=1 Case Study

N=1 studies have the ability to highlight mechanisms, suggest new theoretical perspectives, and highlight disconnect between research and application [23-25]. Additionally through a N=1 study we are able to provide qualitative details that large-N controlled studies often lack. In the same way Danielak analyzed Michael's sense-making as a distinct identity, rather than a practice, that clashed with what he believed to be valued by the engineering program [23], we aim to analyze Projector Man's problem-solving also as a distinct identity that strengthens engineering identity. Projector Man's experiences provide an opportunity to analyze a relatively understudied area within identity research. Through them, we are able to observe problem-solving as an identity and its interactions with engineering identity in non-engineering contexts. We chose to examine this unique case to highlight differences from 'typical' engineering students - a student who lacks typical identity makers yet because of a strong sense of a problem-solving identity persists in studying engineering.

Data Collection

This N=1 case study originates from a larger study examining identity and affect of first- and second-year engineering students enrolled at a small liberal arts university [26]. Students had to be taking their first semester of coursework in the engineering program at the time of enrollment in the study. Participants completed a survey and interview at the end of each semester over the course of two years. During the interviews, participants were asked to reflect on their experiences and involvement in mathematics, science, and engineering. Questions in the interview were geared towards understanding the participants' identity and affect. These interviews tended to last between 1 and 3 hours depending on the depth of the participants' responses.

Preliminary Analysis

Interviews were professionally transcribed, and then the transcripts were analyzed using thematic coding and discourse analysis. The transcripts were first coded for expression and regulation of emotions regarding math, science and engineering. Next we coded for utterances that met our definitions of performance, competence, interest, and recognition. Discrepancies and questions were settled through debate and discussion. The initial analysis of each transcript was used to create a memo which summarized main themes surrounding affect and strength of identity.

Projector Man was selected for this N=1 case study due to the unique role their problem-solver identity played in influencing their engineering identity during all four of their end of semester interviews. The ways in which Projector Man talked about the role of problem-solving in their identity was uncommon in our data collected. Many of our participants articulated that problem-solving was an important skill an engineer should have. However, Projector Man articulated problem-solving as an identity across multiple contexts. Intrigued by Projector Man's atypical identity, we selected them for further in depth analysis. Projector Man was a self-selected pseudonym chosen during the consent process when the participant used he/him pronouns. When Projector Man later told the interviewer they identified with "any" pronouns, they were given the option to change their pseudonym, but decided against it because their chosen pseudonym carries meaning behind their engineering experience. For consistency, we use they/them pronouns when describing Projector Man throughout this paper.

N=1 Case Study Analysis

Further analysis was conducted by the first two authors with specific attention paid to problem-solving. Each transcript was read through and utterances regarding problem-solving were collected. These utterances were then organized into the following categories: situational context (engineering coursework, theater, life circumstances), attitude towards problem-solving, feelings resulting from problem-solving, and clear description of a problem-solver identity. Next, utterances indicative of a weak engineering identity were compiled from the preliminary analysis. Once all utterances in relation to problem-solving were pulled we finalized which were relevant to our research questions. We moved forward with quotes relevant to articulation of problem-solving identity, situational context of problem-solving, and weak engineering identity

indicators in order to focus our analysis on identity rather than emotions and attitudes.

Results

Projector Man identifies themself as a social "theater kid" and "designer" who, "had to face a lot of life realities" (Sem-4). Projector Man describes what we identified as a mix of weak and strong engineering identity markers, however, they have an overall strong engineering identity. They described strong interest in engineering, positive self recognition, weak performance and competence, and negative recognition from others across all semester interviews.

The following subsections provide evidence to answer our research questions. The first subsection addresses our first question by discussing Projector Man's distinct problem-solver identity and its connection to their engineering identity. The remaining three subsections address our second research question through examining Projector Man's two weak engineering identity markers (performance and outside recognition), application of problem-solving in theater contexts, and application of problem-solving through personal life circumstances, respectively.

Identifying as a Problem-Solver

During each end of semester interview, Projector Man identifies problem-solving as an integral part of their identity. During the first interview at the end of semester one of the study (Sem-1), Projector Man articulates how they feel "least tied to [their] race, gender, and standing" as parts of their identity and place more value on personality. Projector Man considers problem-solving to be part of their identity saying, "The two parts about my personality that are most important to my identity are that I'm a problem-solver and that I'm generally positive" (Sem-1). They described themself as a person, "with passion for engineering and problem-solving" (Sem-2), and view themself as "a problem-solver in every aspect" (Sem-3). Problem-solving continues to be an integral part of Projector Man's identity so much so that they say "not seeing me as an engineer is, to me, not seeing me. Because problem-solving and because being creative is such a part of me that I don't see myself as separable from that on an identity basis" (Sem-4). Their persistence in describing themself as a problem-solver shows how important Projector Man considers it to be for their identity.

In each interview, Projector Man was asked to describe an engineer. A common theme in all four responses was that engineers were people who solved problems. With this belief established, they viewed "being someone who has always solved problems" as an identity that contributes to being an engineer since, "you have to be curious if you're going to be an engineer and you have to love problem-solving" (Sem-3). They see a problem-solving identity as a prerequisite for being an engineer.

Projector Man's identification as a problem-solver is what guides their interest in engineering. They view the formation of a problem solver identity as necessary for their formation of an engineering identity.

> I think because [...] me being a problem-solver is inseparable from me being me, I think that leads me to identify incredibly heavily with engineering. I think because my life has been defined by problems and been defined by challenge, that definitely that leads to

engineering being an integral part of me (Sem-4).

They view themself as a problem-solver first and foremost saying, “at the end of the day I'm not passionate about engineering. I'm passionate about problem-solving. Engineering is the most direct way into that” (Sem-4). Though they developed this identity first, they believe, “problem solving is the only thing that is inseparably intrinsic to engineering” (Sem-4). Engineering is an outlet for Projector Man’s problem-solving identity since they believe that “if you’re an engineer, [...] your job is to solve [problems]” (Sem-3). They say that for engineers, “Your blood, sweat, and tears is solving problems. I think that's what has made me so sure of this major the more I've gone on is I've been solving problems all my life, so now I'm just doing it formally” (Sem-3).

Negative Engineering Identity Markers

Projector Man describes themself as someone who performs poorly on exams and describes negative recognition from family members and engineering peers doubting their belonging and ability to succeed in engineering. This suggests two weak engineering identity markers: performance and recognition from others.

Projector Man describes struggling to perform well on exams across multiple interviews. When reflecting on their physics grades, they say, “So typically, exams are the things that brought me down. And in every other part of this physics class, my average was a 95. In this specific part of this physics class, my average was, I believe, a 55, which was slightly below passing” (Sem-2). This failing grade eventually threatens Projector Man’s standing within the engineering program: when asked if they plan on continuing with engineering coursework next semester, they explain, “I am currently failing one of my classes by 0.3%. And if that grade is brought up, then I will be fully continuing. And if not, then I might have to rearrange my schedule a bit” (Sem-2). Additionally, their poor performance on exams has also caused feelings of self-doubt. When talking about an exam that went poorly during Calculus I, Projector Man explains:

> I knew that I was kind of panicked and I was kind of rushed. And again, I knew that I was under-prepared for it. And as a result of all of those feelings and all of those doubts, they were reflected poorly in my final grade for that exam, and I remember just being hit with this crashing weight of, “Why am I even in calculus?” (Sem-1)

Here, Projector Man’s self-doubts during the exam became amplified once they received their poor grade as they began to question their own standing in engineering courses. Overall, Projector Man’s low grades on exams not only directly threaten their ability to continue in the engineering curriculum, but also amplify any doubts Projector Man experiences about their ability to be successful within engineering coursework.

In combination with poor performance on engineering exams, Projector Man also describes their experience of their family and engineering student peers doubting their ability to be successful within engineering. Growing up, Projector Man’s family consistently expressed negative thoughts about Projector Man’s dream of becoming an engineer. Projector Man describes:

> [...] essentially a childhood and teenagehood of doubt from others. I grew up being told that I’m never going to do [engineering] and that I would never be enough. Even getting to college was a struggle because I had my family say that if I go into engineering that they would not fund me [...] I was getting no support throughout, but I was kind of told that it would be a useless waste of time and that I would never be any good at it (Sem-3).

Here, Projector Man explains that because their family believed they wouldn't be good enough to make it in engineering, they neglected to provide both financial and emotional support for Projector Man through college. Projector Man also struggled relying on their engineering peers for support. They state, "There are a couple of people in my major who I'm not so friendly with, who have at points told me that I don't belong" (Sem-2). Projector Man experiences negative recognition from others in multiple facets of their life that make it harder for them to form a strong engineering identity.

Application of Problem-Solving Within Theater

Projector Man utilizes their strong problem-solving ability to aid in the design of stage sets and lighting configurations for their school's theater department. When asked about their biggest success during Sem-2, Projector Man describes the "incredible moment" they experienced when applying a statics problem-solving process to a piece of the stage set:

> So my biggest success [...] our set for our show had two massive 20 foot walls, one of which had to be anchored down to the other, which was just free floating on wheels [...] And I had the realization of, this wall is a static equilibrium problem, let me solve it [...] And it was a very, very minor thing, but it was an incredibly massive success for me because I was practically implementing the skills that I learned. And that's always the best thing for me is whenever I'm not just showing my knowledge in class, but whenever I'm able to take it outside of class (Sem-2).

Projector Man had a very similar experience the following year when asked to share an experience that made them feel like an engineer:

> [...] We only had 14 conventional lights, and being able to create a lighting design that by multiple professors' admissions was on par with a lab show, which was a tier up [in production quality] [...] that made me feel like an engineer because I took underutilized resources and problem-solved around them in a way no one had seen before (Sem-4).

In both of these experiences, Projector Man displays performance by successfully applying their engineering knowledge to a problem with the real-life stage sets they were building. The combination of these utterances shows the significance that problem-solving outside of engineering coursework has on Projector Man's performance and self-recognition.

This connection to engineering identity is taken one step further by Projector Man identifying and articulating the clear connection they see between theater, problem-solving, and engineering. Projector Man says, "A lot of people don't think of theater as problem-solving, but I definitely think that it is and can be a lot. It is and can be very heavy problem-solving because if something goes wrong during a show, you have to solve that" (Sem-1). With the acknowledgment that theater inherently involves problem-solving, Projector Man's reflection of theater connects to engineering identity markers. They explain, "Working in the [scenic design shop] has been me applying a lot of my engineering skills [...] I'm applying them practical in a real-world scenario and it's been not only useful for keeping my passion going, but for showing me how [engineering skills are] useful" (Sem-4) and, "And so the theater world and being forced to be so creative so rapidly has definitely complimented engineering because it's allowed me to build up that creativity muscle. It's allowed me to get more practice in doing that" (Sem-4). Projector Man sees the benefits of being able to practice and strengthen their problem-solving skills in theater applications. This sustains their interest in engineering and provides an avenue to build

competence, display performance, and gain recognition from others.

Application of Problem-Solving Through Personal Life Circumstances

Projector Man credits their strong problem-solving skills to overcoming challenges in their personal life. The repetition of challenging experiences that have required this skill has built Projector Man's confidence in their ability to overcome future challenges. This sentiment is especially prevalent in Projector Man's interviews when they answer the question, "As you encounter challenges in your [...] engineering classes, do you typically believe you can overcome the challenge?" After Sem-3, Projector Man answers:

> I always think I can overcome a challenge. For me personally, a lot of that comes from having very challenging life experiences. There have been a lot of life experiences that are more difficult to solve and have more variables than any [engineering] problem that I will ever encounter. And while I would not recommend that to any person, it is a benefit to me (Sem-3).

They answer again very similarly in Sem-4. They continue to believe that they can overcome challenges thanks to their life experiences and say, "I definitely think my confidence and my ability to overcome everything would not be so high had I not overcome a lot" (Sem-4).
In combining these answers, it is clear that Projector Man believes they are a strong problem-solver because they have had to overcome many challenging problems throughout their life. This repeated success in overcoming life challenges in combination with the possessed confidence in their own ability to solve future engineering problems is a clear display of engineering competence and performance.

In the same way that Projector Man can apply problem-solving skills learned from outside sources to their coursework, they can also apply problem-solving skills learned from coursework to their personal life. A specific example of this happened before the start of Sem-3 Projector Man's status at their university was at risk for "financial reasons" (Sem-3). Projector Man realizes this was a very similar problem they had tackled during their design class and describes, "So, I pulled open my old design homework, used a spreadsheet from it, changed some variables, and solved problems" (Sem-3). They further explain, "And solving that problem, I think, and also solving that problem and the experience overall, the intensely negative experience, but the experience overall kind of made me more self-assured, and made me more confident in my engineering abilities" (Sem-3). It is important to note that within this example Projector Man displays engineering performance by gaining more confidence in their problem-solving talents after successfully solving a real-life problem.

Discussion

RQ1: How is a problem-solver identity distinct from an engineering identity?

Projector Man formed their identity as a problem-solver prior to forming their engineering identity, which has resulted in a distinction between the two identities. Projector Man's identity as a problem-solver began developing prior to and outside of their engineering experiences. Projector Man's problem-solving identity is defined by their interest in and ability to overcome challenges presented to them regardless of the circumstances. Their identity as a problem-solver

encompasses more experiences than their identity as an engineer. These two identities contribute to each other in ways that strengthen both identities while still remaining distinct.

Projector Man's problem-solver identity strengthens their engineering identity. They are able to strongly identify as an engineer because they have a strong identity as a problem-solver. They consider problem-solving an integral part of their identity and believe that part of what an engineer is is a problem-solver. Additionally, their interest in problem-solving maintains their interest in engineering and solidifies their decision to pursue the engineering major.

Although it is clear that Projector Man's problem-solving identity developed first, we lack information on how this development came to be. Interview questions mainly focused on the college experience and understanding engineering identity. Due to this, we cannot explain how the formation of a problem-solving identity is distinct from that of an engineering identity, although we have hints from Projector Man's descriptions of developing an interest in engineering based on reading *The Martian*, a book in which the main character problem-solves through extreme circumstances. Information on problem-solving identity was described mainly within the context of engineering and outside contexts were introduced to the conversation with minimal or no prompting. Projector Man often alludes to life challenges that helped develop their identity as a problem-solver, but remains vague about the specifics (which were outside the scope and intention of the interview). The lack of specific questions about developing a problem-solving identity means that we are still missing nuanced details.

RQ2: How does problem-solving outside of typical engineering coursework and activities influence engineering identity?

Projector Man's experience with problem-solving outside of typical engineering coursework reinforced their interest, performance, and self-recognition, directly compensating for their negative performance in engineering coursework and negative recognition from others.

Projector Man's self-reported negative performance on engineering exams is compensated for by their high showings of performance through theater and personal life circumstances. Although Projector Man struggled to demonstrate their knowledge on engineering exams, they excelled at applying it outside of engineering settings. This aligns with the achievement-based aspect of performance: an ability to outwardly express engineering skills. Projector Man's difficulty in outwardly expressing their knowledge learned in class in an exam setting is reflected by their poor exam grades which, in turn, hinder their confidence in their academic standing. However, Projector Man's achievements outside of typical engineering coursework including building a stage set wall, designing stage lighting, and overcoming financial challenges, exemplify their positive view of performance when they personally relate these achievements to engineering themself. These successful problem-solving experiences outside of traditional engineering activities highlight Projector Man's ability to apply engineering skills to real-world applications, ultimately strengthening their engineering identity.

Similarly, Projector Man's negative recognition from others (family members and engineering student peers) is compensated for by their high self-recognition enhanced by their experiences outside of typical engineering settings. Projector Man attributes their engineering identity to their

problem-solving abilities, noting they recognize themself as an engineer because they are a problem-solver first. Recognizing challenges outside of typical engineering activities as valid avenues to practice problem-solving has repeatedly built up Projector Man's confidence in their own ability and self-recognition as an engineer. This in turn has compensated for the lack of external validation and promoted the development of a strong engineering identity.

Conclusion and Implications

Despite their self-perceived negative performance and negative recognition from others as an engineer, Projector Man still strongly identifies as an engineer. Through this work we have demonstrated how Projector Man has a problem-solver identity they view as distinct from their engineering identity and how the use of this identity in non engineering contexts strengthens their engineering identity. The ability to utilize problem-solving skills in theater and other life circumstances gave Projector Man a unique context in which to display performance, maintain interest, and receive recognition in positive ways. These experiences greatly strengthened Projector Man's engineering identity.

Projector Man also highlights the importance of distinguishing recognition from others and self-recognition as two important subfactors of recognition, something not often included in other quantitative identity studies. People who Projector Man deemed important to them (family and engineering peers) did not see them as an engineer. Despite this they still identified themself as an engineer. Self-recognition became more important for their engineering identity.

Despite limitations, this work suggests that there is potential to create an intervention to strengthen engineering identity that works through identification and discussion of transferable identities in non engineering contexts. Class discussion started at the beginning of students' first engineering class or situations in curriculum that make students call back to and reflect on outside of class experiences can help them understand how they can bring previous experiences not related to engineering into an engineering space [27]. These interventions would provide more flexible opportunities to develop engineering identity to make up for circumstances where students fail to develop these traits in typical classroom settings. More case studies with a wider variety of engineering students could shed light on which identities students more readily relate to engineering because other students may not view problem-solving in the same way Projector Man does. Developing students' ability to recognize their other identities that complement and strengthen engineering identity has the potential to increase retention of students who possess indicators of a weak engineering identity within engineering contexts.

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