

# ME 450 Design Review 1

## Team 3: Automated Gel Casting

Halia Andrews, Nick Kuske, Erica Santos, Sophia Newton, Jason Zhu

### REVISED ABSTRACT

Polyacrylamide gels for electrophoresis can be bought precast or can be manually cast. These two options present a tradeoff between labor time and price. Our team plans to solve this dynamic through automation. Our pursuit is to remove the labor cost of in-lab casting, while maintaining the inexpensive nature of creating gels in-lab. Additionally, our team strives to use this automation to increase reproducibility and reduce error of the gel casting capabilities in the lab. Our current project goal is to produce a prototype that creates viable gels, while satisfying the previous two objectives on accuracy and economic cost.

### PROJECT INTRODUCTION

Polyacrylamide gel electrophoresis (PAGE) is a trusted technique for separating proteins by molecular mass [1]. PAGE is a common technique used in labs worldwide to isolate proteins, study their composition, and compare their molecular weights. An essential component of the PAGE process is the polyacrylamide gel through which the proteins are separated. The success of a PAGE experiment is directly dependent on the quality of gel that is used. Likewise, the consistency across experiments is also a factor of gel uniformity.

For a lab regularly conducting PAGE experiments, there are currently two options to access a supply of polyacrylamide gel. The lab can either make the gels onsite or order precast gels from a company that mass produces them. Precast gels offer a level of convenience and reliability that gels made onsite lack. This is because gels made onsite require up to two hours of preparation time from an experienced lab technician and demand precise measurements with little room for human error [2]. Still, the practice of producing gels onsite is widespread throughout the PAGE community. Hand cast gels are fully customizable and up to 36.59% less expensive than precast gels because of the lower material cost for gel production compared to manufacturing upcharges.

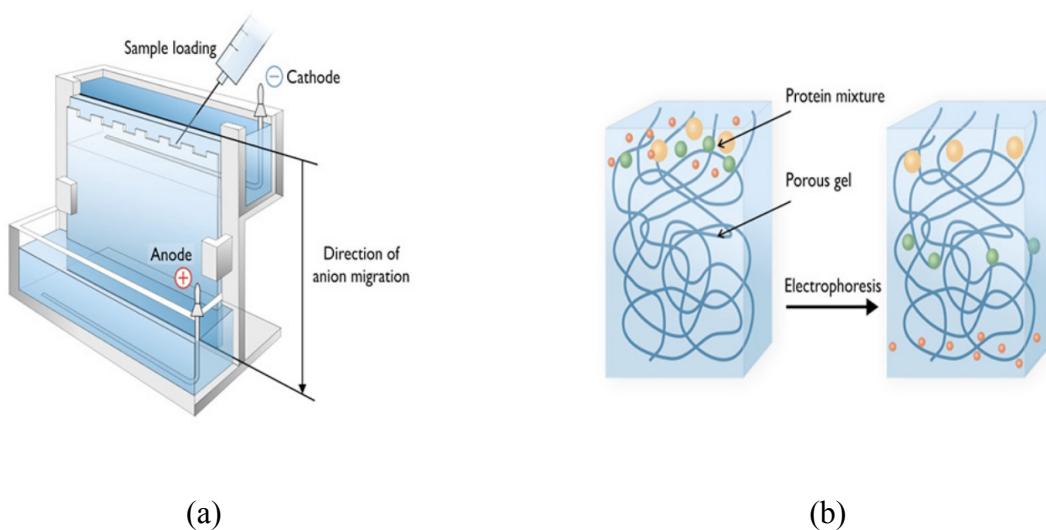
Inspired by the benefits of lab made gels, we and our sponsor Duane Day of Innovative Research Inc. seek to automate small scale gel production in order to improve its convenience and reliability. Mr. Day has been working with gel electrophoresis for over thirty years and this project is benefitting greatly from his long-time consideration of automating the gel making process. His previous work considering this problem has led to us taking the approach of designing an apparatus around current gel making equipment. We expect that automating the casting process, in-lab, may result in a cost reduction of 65.83% from precast gel prices without factoring in the cost of the machine.

The major objective of this project is to develop an automatic gel casting system that is competitive against precast gels in the areas of convenience and reliability. The final deliverable will be a prototype that can produce a uniform gel with no human interaction beyond the initial setup. Engineering standards applicable to this project are primarily related to the safe chemical

handling required by the gel making process. Safety guidance was provided by the following standards: the OSHA General Industry Standards (specifically the Hazard Communication, Hazardous Materials, Machinery and Machine Guarding, and Electrical specifications), the “NIOSH Guide to Chemical Hazards, and “Prudent Practices In The Laboratory: Handling and Management of Chemical Hazards by the Board of Chemical Sciences and Technology.”

## BACKGROUND

Polyacrylamide gel electrophoresis (PAGE) was introduced in the 1950’s as a reliable method of separating proteins by molecular mass [1]. It has been critical to studies in RNA, detecting pathogens, and forensics [3]. PAGE involves running a current through a gel, which draws charged proteins through the gel matrix. The distance that the proteins travel is logarithmically related to their molecular mass, with the smallest proteins traveling the farthest from the sample wells [4]. Figure 1a shows the polyacrylamide gel in its vertical electrophoresis stand with samples being loaded into its wells. The gel is placed in a running buffer that allows a current to flow through the gel from the anode to the cathode [5]. Figure 1b shows proteins with the smallest molecular mass traveling the fastest through the gel matrix, leading to protein separation by molecular weight.

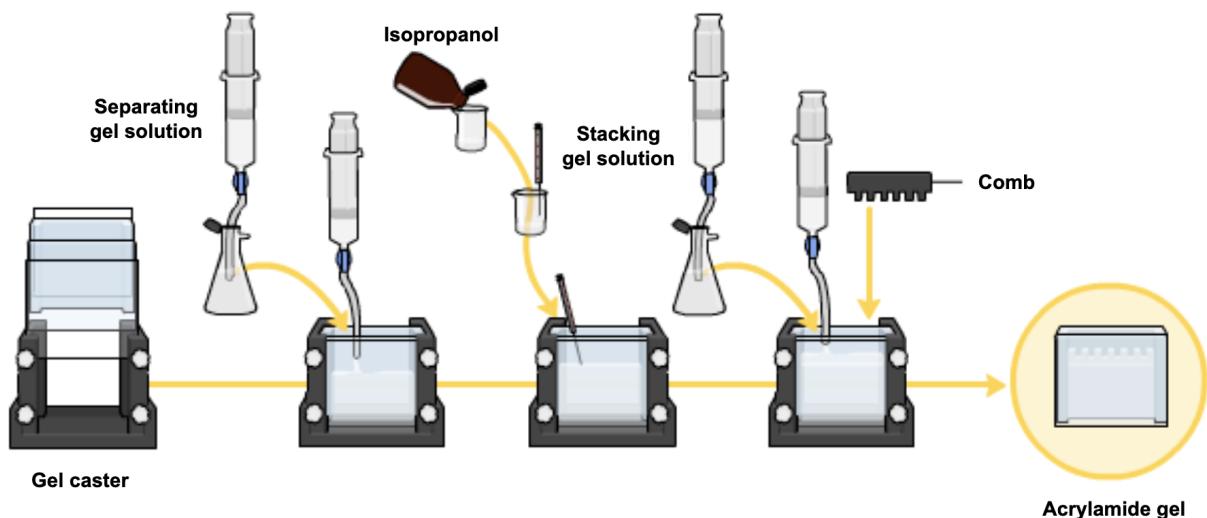


**Figure 1:** (a) polyacrylamide gel in its vertical electrophoresis stand, with samples being loaded into its wells. (b) proteins with the smallest molecular mass traveling the fastest through the gel matrix, forming bands [6].

Basic gels are made from polyacrylamide, gel buffer, sodium dodecyl sulfate (SDS), water, ammonium persulfate (APS), and tetramethylethylenediamine (TEMED) [2]. The percentage of polyacrylamide affects the density of the gel matrix, and therefore what ranges of protein sizes can be sorted on one gel [7]. Common percentages of polyacrylamide range between 7.5% and 20% [8]. Gradient gels vary in percentage of polyacrylamide along the direction of protein travel, most commonly varying from 4-20% or 8-16%. Gradient gels are used when samples containing a broad range of molecular weights must be separated. APS

initiates the polymerization of acrylamide solution, with TEMED acting as a catalyst for the reaction. The polymerization reaction is exothermic, so its speed must be carefully limited by the concentrations of TEMED and APS in order to prevent rapid heating that risks the formation of non-uniform pore structures. The gel buffer prevents the gel pH from changing as protein samples are added to it. Water and SDS are used to dilute the other reagents to the proper concentration [9].

The procedure for producing a polyacrylamide gel as we observed in a demonstration by our sponsor is highlighted in Figure 2. The gel mold is composed of two glass plates, spacers for the plates, a stand, and a rubber gasket to keep gel from leaking out of the base of the glass plates. Polyacrylamide is mixed with the previously mentioned reagents to make the separating gel solution, TEMED is the last reagent to be added because it kicks off the catalyzation reaction. Once mixed, the separating gel solution is carefully poured between the glass plates on the casting stand. This step is done using gloves because acrylamide is neurotoxic before it polymerizes. Isopropanol is added to the top of the separating gel solution immediately and the gel is left to fully polymerase over the period of 30 minutes to an hour. Leftover separating solution is used as an indicator of full polymerization. Once the separating gel has fully polymerized, the isopropanol is removed by tilting the casting stand to allow the isopropanol to run out of the mold and onto a paper towel. The stacking solution is mixed using the same reagents as the separating gel, but at different concentrations. The stacking solution is purposefully overflowed, out of the plates, in order to ensure the casting mold is full. The well-forming comb is laid on top of the stacking solution immediately. The comb must be laid in a way that does not cause bubbles to form beneath it; this is often done by inserting the comb at an angled direction. The stacking solution is left to polymerize for 15 - 30 minutes before the gel is ready to be used. The comb must be extracted before gel use to open up the sample wells for the proteins [2].



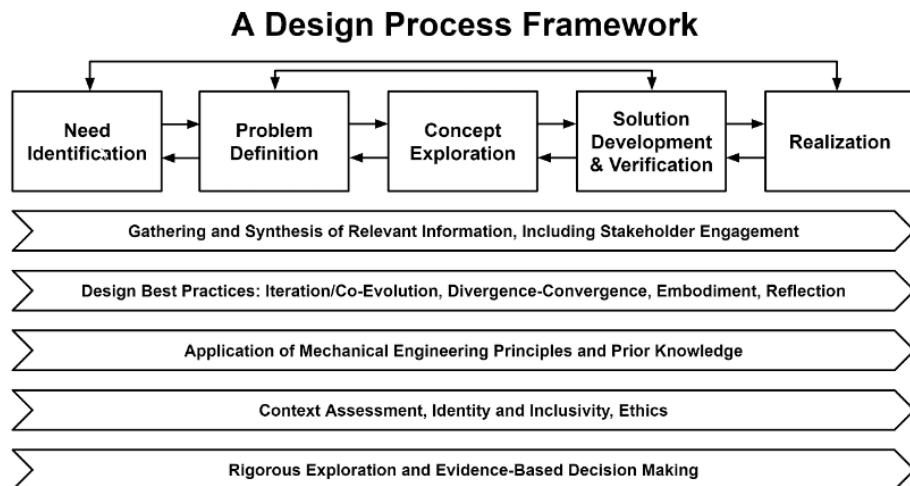
**Figure 2:** PAGE casting procedure, as conducted by Innovative Research Inc. [2][10]

Companies such as Bio-Rad and Invitrogen mass produce gels to distribute to laboratories. These gels cost within a range of \$12-\$20 and have a shelf life of up to 12 months [11]. These gels are convenient because they save lab technicians time but their limited shelf life, their high cost, and their inability to be customized make them imperfect solutions for many labs. Additionally, there are negative environmental impacts from this process as precast gels come in plastic casings which are discarded and must be shipped from the manufacturer to the lab [2].

Casting by hand requires extensive training (about 20-30 gels) and a lifetime of experience to perfect the process. The likelihood of inconsistencies in manually cast gels is higher compared to precast gels because of the human factor involved [8]. Casting manually requires up to two hours of lab technician attention, and requires the technicians to handle neurotoxic chemicals. Casting gels by hand also requires specialized casting equipment sold by many of the same companies that offer precast gels.

## DESIGN PROCESS

The design process we decided to follow for this project is the Design Process Framework outlined by the ME 450 course, shown in Figure 3.



**Figure 3:** ME 450's Design Process Framework

This methodology is stage based and iterative – two components we wanted to ensure we had. We wanted a methodology that includes space for iteration. Another important feature to note are the arrows across the bottom of the framework. Out of all the methodologies analyzed in the course, this process was the only one to include features to be considered over the course of design. Our exact process to date has included multiple iterations through problem definition and need identification, and we expect to continue looping through the stages.

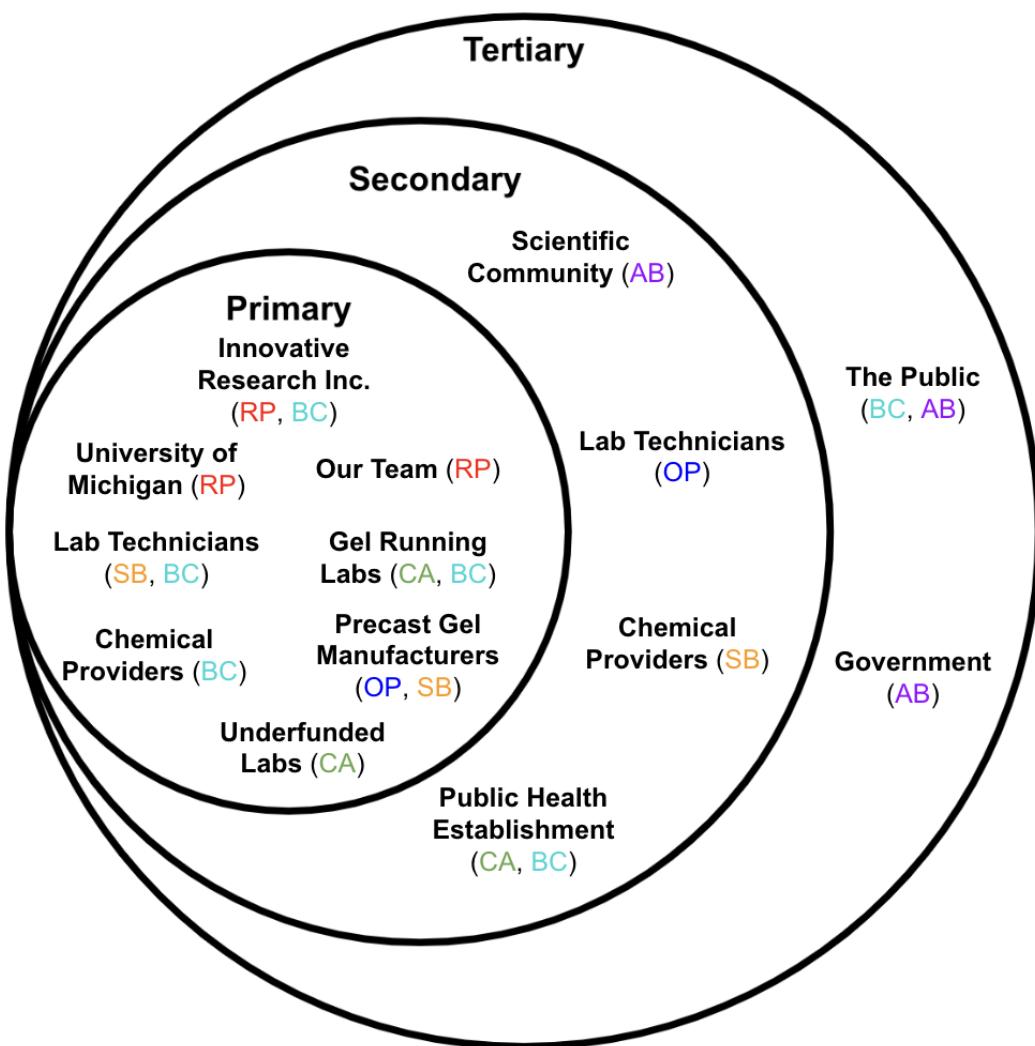
Another methodology considered was Pahl and Beitz's stage-based model (Appendix, A.1) for mechanical design [12]. It was similar to the one provided by the course, and included the side considerations for outside factors. However, the constraint of combining “process documentation” and “detailing” at the end of the process was the deciding factor against it. We

could not see how we could effectively merge the methodologies with the constraints of the course (and design report milestones), our team's documentation preferences (to detail everything as we go), and the ideology of Pahl and Beitz's method.

## DESIGN CONTEXT

### *Stakeholders*

The laboratory setting of our project is directly tied to the larger scientific community. Within the context of this course and our project scope, we have identified primary stakeholders to be the internal and external stakeholders. Internal primary stakeholders are Innovative Research, Inc., Our Team, the University of Michigan. Our external primary stakeholders are: Lab Technicians, Gel Running Labs, Chemical Providers, Precast Gel Manufacturers, and Underfunded Labs. These groups, along with the secondary and tertiary stakeholders, are visualized in Figure 4, our stakeholder map.



**Figure 4:** Target graphic of our primary, secondary, and tertiary stakeholders.

We assume that the internal group of stakeholders would positively benefit from the adoption of this technology. Within the external group of stakeholders, we believe lab technicians, underfunded labs, gel running labs, and chemical providers would all benefit from the technology, by reducing costs, increasing lab work efficiency, and minimizing lab time with menial tasks. However, if the technology becomes widespread, precast gel manufacturers and lab technicians could be negatively impacted. Precast gel manufacturers may lose customers if labs choose to cast gels in-house. Additionally, an automated system would reduce the scope of work or even replace lab technicians who primarily cast gels.

Gel electrophoresis is a standard laboratory practice that has aided medical and scientific exploration. Our process, PAGE, is used to separate proteins for further analysis and has wide ranging implications in applied biology. The effort to minimize menial lab work and make lab technicians more efficient is driven by the social desire to increase research productivity within biological labs.

As a business with economic responsibilities, our sponsor's profit is their priority. When considering our stakeholder ecosystem, our sponsor's focus on profit may limit the scope of social impacts our final design has, depending on how accessible they decide to make its market price. Their next focus area is the potential environmental and social impacts. The order of these priorities has already had an impact on the actual design of our project. This is because the functionality of our final design was clearly defined by our sponsor to meet their desires. The environmental and economic consequences we envision for our project are mostly a result of the overall functionality rather than the specific manner of implementation. Therefore, our freedom in making design decisions will not be greatly affected by the overall social impact of our project.

### *I.P. and Sustainability*

As requested by Innovative Research Inc. our team has transferred our intellectual property rights to them within the extent of this project. Intellectual property rights play an important role in examining the social context, sustainability, and stakeholder environment as it will relate to who has access to the technology we will be developing. Since our sponsor has prioritized profitability, our team believes that the primary effect of our sponsor retaining the intellectual property rights will be to reduce the economic access to our device. The principal cost to acquire our final product will limit who has access to it, but if a lab has the needed capital it will likely be much more efficient for repeated use than buying precast gels. This has the potential to make the device favored over the current precast gel market, depending on the initial price set by our sponsor. That said, our sponsor will benefit from the price being as high as possible; therefore, our design may not actually impact who has access to gel electrophoresis.

Beyond accessibility, the effects of intellectual property are relatively minimal, as there is currently no market-available solution that is comparable. With a lab-bench casting machine not yet invented, the primary limitations on our design process will be on what processes we can use

to achieve our goals. Patents on mixing, measuring, fluid driving, and clamping will affect what solutions our team can use.

If the monopolization of our end-product by Innovative Research Inc. does not result in limited access to the machines but rather their widespread use, there may be significant sustainability effects. The increased ease of gel production will likely lead to a rebound effect, with gels being used less efficiently and more gels being produced [2]. This would increase the demand for materials and their shipment, increasing the carbon emissions associated with chemical manufacture, disposal, and transport. The machines themselves will also require electricity, which is a predominately fossil fuel powered industry. One possible solution to these environmental costs is to make the machine able to cast gels with variable lane-counts, so that users can create a gel with just as many lanes as needed, limiting excess waste. This, however, is a complex change that would require many resources in development and increase the end cost of our product.

Even though there are potential drawbacks in sustainability due to the rebound effect, power draw, and cost of manufacturing our device, we believe that our product will be beneficial in terms of sustainability. We believe that the impact of the rebound effect and increased electrical power use, will cancel to some extent with the reduction in packaging and shipping associated with the precast gel purchases. We believe that in the long term, the social benefits of increasing research productivity will be more impactful than the potential environmental trade-offs.

### *Ethics and Power*

The main ethical dilemma we expect to face is if the automation of gel casting becomes too widespread. If this occurs, the decrease in the workload for lab technicians could potentially lead to fewer hours and fewer employment opportunities. As for the team's personal ethics, we believe that they align with the professional ethics we are expected to uphold by the University of Michigan and future employers.

The power dynamics among our teammates is strict equality. We all have provided, are providing, and will provide work and effort towards the project goal. Our project sponsors are our primary stakeholder and are the ones who have provided design requirements; they serve as our mentors. The end users, or lab technicians, have also contributed to the design requirements as they have the most experience with casting gels. For our project, Dave Ginsberg, a lab technician from Innovative Research Inc. will serve this role.

When considering the stakeholder requirements, engineering specification, and this project as a whole, our team only considered the opinions and technicians of a single lab technician, Dave Ginsberg. While Dave Ginsberg has extensive expertise, there may be efficiencies that other lab technicians may include in their own PAGE process. Because of this, our design may suffer from this lack of outside expertise. Inclusivity is also an issue when it comes to IP. Our team has assigned our IP to Innovative Research Inc. which means that they will maintain sole rights to our automated casting machine. This has the potential for Innovative

Research to create a temporary monopoly on the automated casting machine market, increasing the principal cost of the device. With a high principle cost, some labs may not be able to afford the device and may suffer exclusion from the benefits of our device.

## USER REQUIREMENTS AND ENGINEERING SPECIFICATIONS

### *Specifications and Marketability*

Stakeholder Requirements [2]	Engineering Specifications	Importance [14]
Functional Gels	95% of gels do not display a meniscus, warping, or separation	1
Accurate	Chemical measurements made with < 5% accuracy	2
Minimal Human Intervention	< 3 human interventions per gel, taking < 5 minutes total per gel	1
System Compatibility	Compatible with systems < 14 x 11 x 1 cm in < 5 minutes	3
Less Expensive	Cost to produce a gel is < \$4.52	2
Easily Maintainable	< 5 minutes of maintenance per gel	1
Chemical Containment	0 chemical exposures to a pH outside of 6.5-8.5, temperatures outside of 45-85°F, and any organic material	1

**Table 1:** These requirements and specifications were generated by a stakeholder interview with our sponsor, a design consultant, and a lab technician from Innovative Research Inc. After their generation, the specifications and requirements were further refined by obtaining both an approval and a priority ranking in a second, follow up interview. Note that importance is ranked from 1 (most) to 3 (least).

After the generation of these requirements and following the feedback provided to us during design review 1 from our sponsor and peers, we added the additional priority importance metric to our specifications. In addition to the requirements and specifications above, our interviews also displayed a set of desires that were deemed to be outside the scope of our project. These desires included the ability to produce gradient gels and to have online or app compatibility. These desires are further developments of our project which we have ensured are possible additions to our design. While gradient gel creation remains outside of our project scope, we detail a possible expansion for gradient solution capabilities in the First Selected Concept section.

Focusing on the stakeholders chief priority, our team examined profitability first. Initially, our team did preliminary research to ascertain whether there is a large enough market to incorporate another gel casting solution. We found that the gel electrophoresis market was estimated at \$2.3 billion [15]. After establishing the market size, our team's next step was to perform a preliminary cost analysis, to discern whether our project would be able to produce an economically viable solution.

Cost Source	Precast Gel [16] [17]	Manual Casting [18]	Automated Casting
Materials	\$13.2	\$0.65	\$0.65
Labor [14]	\$0	\$7.72	\$3.86
Total Cost	\$13.2	\$8.37	\$4.51

**Table 2:** Using the gel creation protocol and material prices from Innovative Research Inc, alongside the average biolab technician wage from the Bureau of Labor Statistics and the prices of precast gels from Millipore, ThermoFisher, and Bio-Rad, our team was able to compile the cost calculations above.

Our preliminary expectation is that a final product price may be \$750-\$1,000 based on our project funding, a typical markup rate of ~50% [19], and a generous range of manufacturing costs. Using this estimate alongside the results of Table 2, we believe our device could return on its initial capital investment between 86-260 gels produced depending on the final price and whether a lab hand casts or buys precast gels. Notably Table 2 does not include the cost that is associated with training lab technicians (which can take up to 20-30 gels), failed gels, and shipping costs. Based on our survey of these factors, we believe our final product may return on investment earlier than we expect from this calculation. As profitability is our clients primary focus, this analysis deserves much deeper consideration after we have a more concrete price estimate for our product.

If our automation were to gain gradient gel casting capabilities, the return on investment would be fair faster and the convenience much greater than expectations explained above. Gradient gels are substantially more tedious to manufacture and require nearly twice as many measurements from a technician [5]. This is the domain in which automation would have the greatest impact with reliability and convenience, it is for these reasons that we believe it would be substantially more economically successful with this capability.

### *Current Standards and Regulations*

When researching standards, our team found a set of codes and standards that we believe following will improve the quality of our design. Because of the nature of our device, our team will need to consult the OSHA General Industry Standards [20] (specifically the Hazard Communication, Hazardous Materials, Machinery and Machine Guarding, and Electrical specifications). Additionally, our team plans to review the “NIOSH Guide to Chemical Hazards” [21] and “Prudent Practices In The Laboratory: Handling and Management of Chemical Hazards by the Board of Chemical Sciences and Technology” [22]. These standards and guidelines will continue to inform our design decisions as our team moves forward.

## PROBLEM DOMAIN ANALYSIS AND REFLECTION

While trying to invent a gel casting machine, we will likely encounter problems with getting the gel to polymerize properly and getting our measurements to be precise enough to achieve the necessary concentration of chemicals. We plan to tackle these challenges by consulting with our sponsor, biolab technicians, labs, and current industry figures in order to gather ideas and gain industry knowledge necessary to design our product. We will need this industry knowledge in order to accurately predict the amount of time for polymerization to occur and to predict the concentration ranges that will produce a viable gel. One method that we plan to use to address some of these issues is to gain experience casting the gel ourselves manually to provide us with some insight and general familiarity with the process. We also need special equipment such as the casting panels and lab-grade pipettes to dispense our gel ingredients accurately. Our sponsor has agreed to provide us with these specialized equipment.

We expect to have difficulties with finding certain details to drive our specifications. The overall goal of our project is to create a replacement for the precast gel industry, so we wanted to base our specifications on the standards of how precast gels are created. Unfortunately, the process of making precast gels appears to be a closely guarded industry secret from our preliminary research, and it's difficult for us to find their specifications. These information gaps will make it harder for us to benchmark our product against the incumbent in order to accurately quantify tradeoffs and advantages for our product. We can try to make up for this information by reaching out to other labs that regularly use precast gels so we can at least understand their usages and advantages better.

## PROJECT PLAN

The original scope of this project as proposed by the sponsors included an automated casting machine that could be remotely operated via an app downloaded on one's phone. After discussing needs, determining the functional requirements, and consulting with our sponsor, we have reduced the scope from the original request. The revised design scope is an automated gel casting machine that is initially setup by the user; thus, our scope no longer includes remote start-up capabilities. Because of these alterations, we believe we have narrowed the scope to what is achievable for one semester. In order to track our progress throughout the semester, we have created a Gantt chart which is located in the appendix.

Initial tasks and milestones for our project include continuing background research, which will allow us to better understand our project and functional requirements. Research will be conducted by all team members. This research will include patent information, component design, and specifications of pre-built components. Additionally, lab certification and lab access is vital for gaining experience in producing gels. While we have user feedback from our sponsors, our sponsor and our team agreed that our own firsthand experience will be extremely valuable in producing a design. After completing the EHS\_BLS025w Chemical Laboratory Safety course, each member casted a gel under supervision of an experienced lab tech. Taking what we have learned by casting gels ourselves, our team now plans on working through concept

generation to determine approaches to automating the process and what restraints may be limiting our design.

These tasks contribute to research and concepting, our initial steps on our critical path. The critical path in order of precedence is research, concepting, solution selection, solution refinement, prototyping, and testing. We believe that by following these steps the number of design obstacles will be minimized while also maximizing work efficiency within the span of this semester.

According to ME450, our budget is \$400 for the physical prototype. Our sponsor is providing a Bio-Rad casting kit and gel ingredients as well as pipettes, so that we are able to gain insight from casting gels ourselves. Additionally, we must consider the tradeoffs between precision and cost effectiveness. After narrowing our scope, we believe that our project is achievable within one semester, with this budget, and number of people.

## CONCLUSIONS

Within the current market, labs can purchase precast gels or create them manually. These two options present a tradeoff between labor time and price, and our team plans to solve this dynamic through automation. Ultimately our objective is to reduce the time, cost, and error involved in polyacrylamide gel casting, while furthering the reproducibility, viability, and common access of gel electrophoresis. Our current target is to produce a prototype that produces viable gels, while optimizing the previously stated objectives. While we are producing this prototype, it is important to our team to consider accessibility, inclusivity, as well as social and environmental sustainability. As discussed earlier, we are concerned about our problem space's potential for the rebound effect, monopolization, and exclusivity. As we move forward, our team will be making the mitigation of these possible negative effects a design priority, as our stakeholders are not limited to our sponsor and our responsibility is to all of them as well as society.

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## BIOS

### Sophia Newton



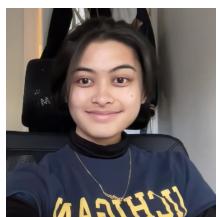
Sophia is a senior finishing her B.S.E. in mechanical engineering with a minor in creative writing. She has enjoyed working with robotics in space, surgical, and ocean applications. Sophia plans to study robotics further in a masters degree or pursue a full time position in space exploration technology - there's still time to choose! Whenever she isn't working on the 450 capstone project, Sophia enjoys being outside and writing silly stories.

### Halia Andrews



Halia is a senior pursuing her B.S.E. in Mechanical Engineering. Halia has spent several years working as a Technology Intern, but plans on eventually expanding her career to robotics. After graduation, Halia plans on commuting from her home in Frankenmuth, MI, to Nexteer Automotive based in Saginaw, MI. In her free time, Halia enjoys crocheting and playing with her cat, Chai.

### Erica Santos



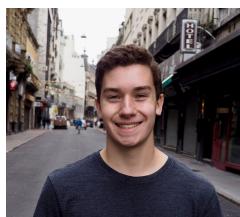
Erica is a senior finishing her B.S.E. in Mechanical Engineering, Minor in Computer Science, and concentration in the Program in Sustainable Engineering. To merge these interests and experiences, she is planning on going back to school for a Master's in Robotics, focusing on mechatronic design. Outside of academics, she competes in ballroom dancing and loves to rollerblade, read, and sketch.

### Jason Zhu



Jason is a 5th year student finishing his B.S.E. in Mechanical Engineering and Computer Science who has a strong interest in technology and robotics. Throughout college, he has done internships in the automotive and consumer electronics industry and spent two years on the Michigan Solar Car team as an aerodynamics engineer. After graduating in December, he will be joining a Bay area startup focusing on software for developing autonomous vehicles.

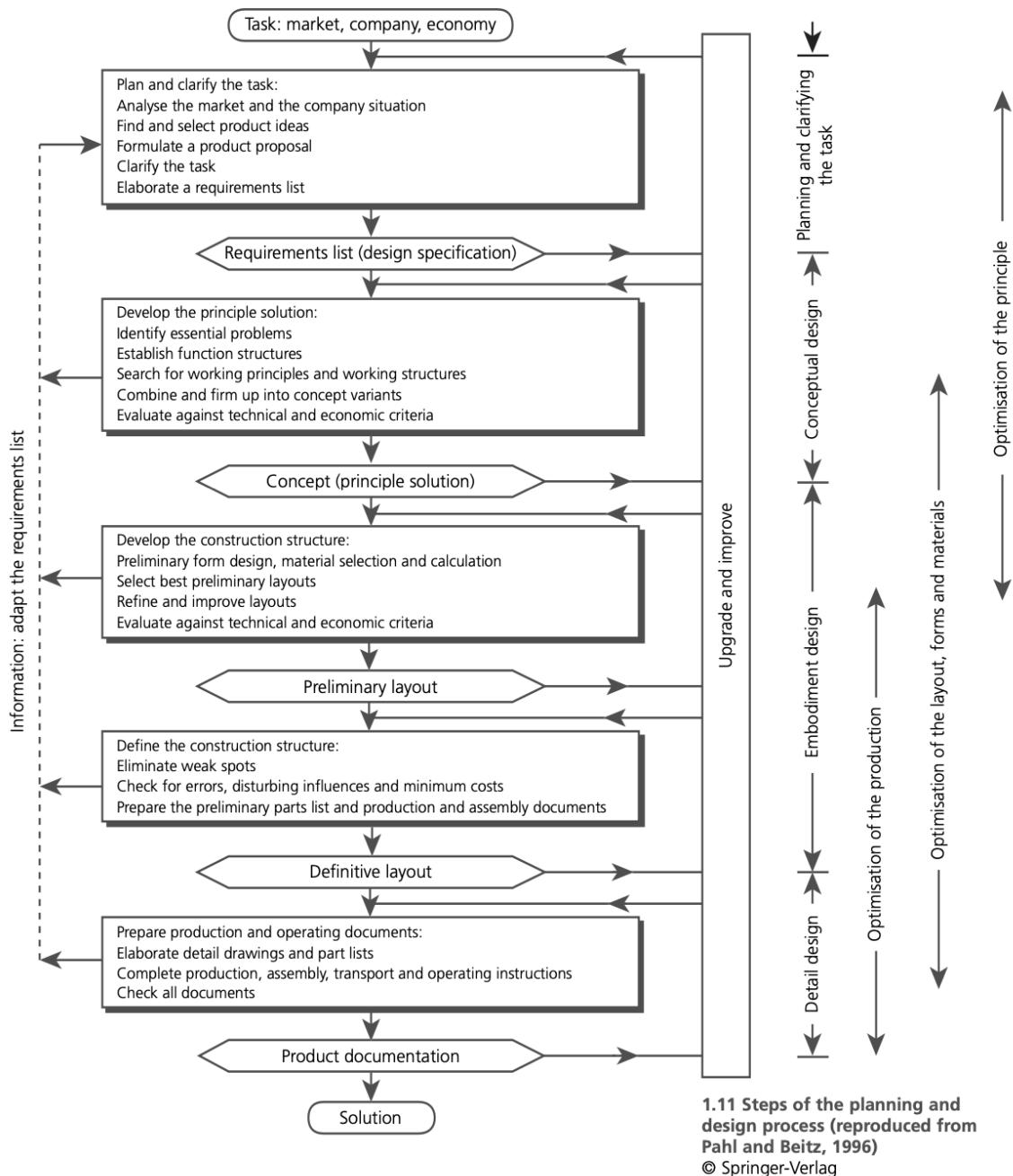
### Nicholas Kuske



Nicholas is a senior finishing his B.S.E. in Mechanical Engineering as well as a Minor in History. While growing up in Grand Rapids, Nicholas spent his summers working in distribution centers. After interning at TGW, he has agreed to return to Grand Rapids and to continue working as an Applications Engineer. Nicholas plans to eventually move from engineering into primary education.

## APPENDIX

### A.1: Pahl and Beitz's Design Process



## A.2: Gantt Chart

### Cast-o-matic Project Gantt Chart

					Design Report/Presentation Due Dates																				
PROJECT TITLE	Cast-o-matic easy pour			COMPANY NAME	INNOVATIVE RESEARCH																				
DATE	9/18/22																								
TASK NUMBER	TASK TITLE	START DATE	DUUE DATE	% OF TASK COMPLETE	WEEK 1 (9/18)					WEEK 2 (9/26)					WEEK 3 (10/3)										
					M	T	W	R	F	M	T	W	R	F	M	T	W	R	F						
<b>1</b>	<b>Design Report 1</b>	<b>10/04</b>																							
1.1	Problem Definition	9/18/22	10/4/22	100%																					
1.2	Background Research and Benchmarking	9/20/22	10/4/22	100%																					
1.3	Stakeholder Analysis	9/18/22	9/20/22	100%																					
1.4	User Requirements and Engineering Specifications	9/18/22	9/26/22	100%																					
1.5	Problem Domain Analysis	9/22/22	9/28/22	100%																					
1.6	Project Plan and Timeline	9/18/22	9/21/22	100%																					
<b>2</b>	<b>Design Report 2</b>	<b>10/25</b>													WEEK 4 (10/10)		WEEK 5 (10/17)			WEEK 6 (10/24)					
2.1	Concepting	10/4/22	10/11/22	20%											M	T	W	R	F	M	T	W	R	F	
2.2	Cast a second demo gel with sponsors	10/10/22	10/10/22	0%																					
2.3	Each team member runs a gel	10/7/22	10/13/22	0%																					
2.4	Develop top 3 concepts	10/13/22	10/18/22	0%																					
2.5	Sponsor Concept Evaluation Meetings	10/18/22	10/18/22	0%																					
2.6	Final Concept Selection	10/19/22	10/20/22	0%																					
<b>3</b>	<b>Design Report 3</b>	<b>11/15</b>													WEEK 6 (10/24)		WEEK 7 (10/31)			WEEK 8 (11/7)		WEEK 9 (11/14)		WEEK 10 (11/21)	
3.1	Order components for final concept	10/21/22	10/26/22	0%											M	T	W	R	F	M	T	W	R	F	
3.2	Test hardware components as it is received	10/27/22	11/1/22	0%																					
3.3	Functional Component Prototypes	11/1/22	11/3/22	0%																					
3.4	Functional Component Prototype Testing	11/2/22	11/5/22	0%																					
3.5	Functional Component Evaluation	11/3/22	11/9/22	0%																					
3.6	Design Change List	11/9/22	11/14/22	0%																					
3.7	Second FC Prototypes	11/14/22	11/17/22	0%																					
3.8	Second FC Prototype Evaluation	11/15/22	11/21/22	0%																					
<b>4</b>	<b>Final Design Report</b>	<b>12/08</b>													WEEK 10 (11/21)		WEEK 11 (11/28)			WEEK 12 (12/5)					
4.1	Final Prototype	11/22/22	11/25/22	0%											M	T	W	R	F	M	T	W	R	F	
4.2	Final Prototype Evaluation	11/25/22	12/1/22	0%																					
4.3	Design Expo Poster	12/1/22	12/5/22	0%																					
4.4	Sponsor Handover	12/5/22	12/8/22	0%																					

