# Understanding Student Learning Progression of Engineering Problem-Framing in Secondary Science Education
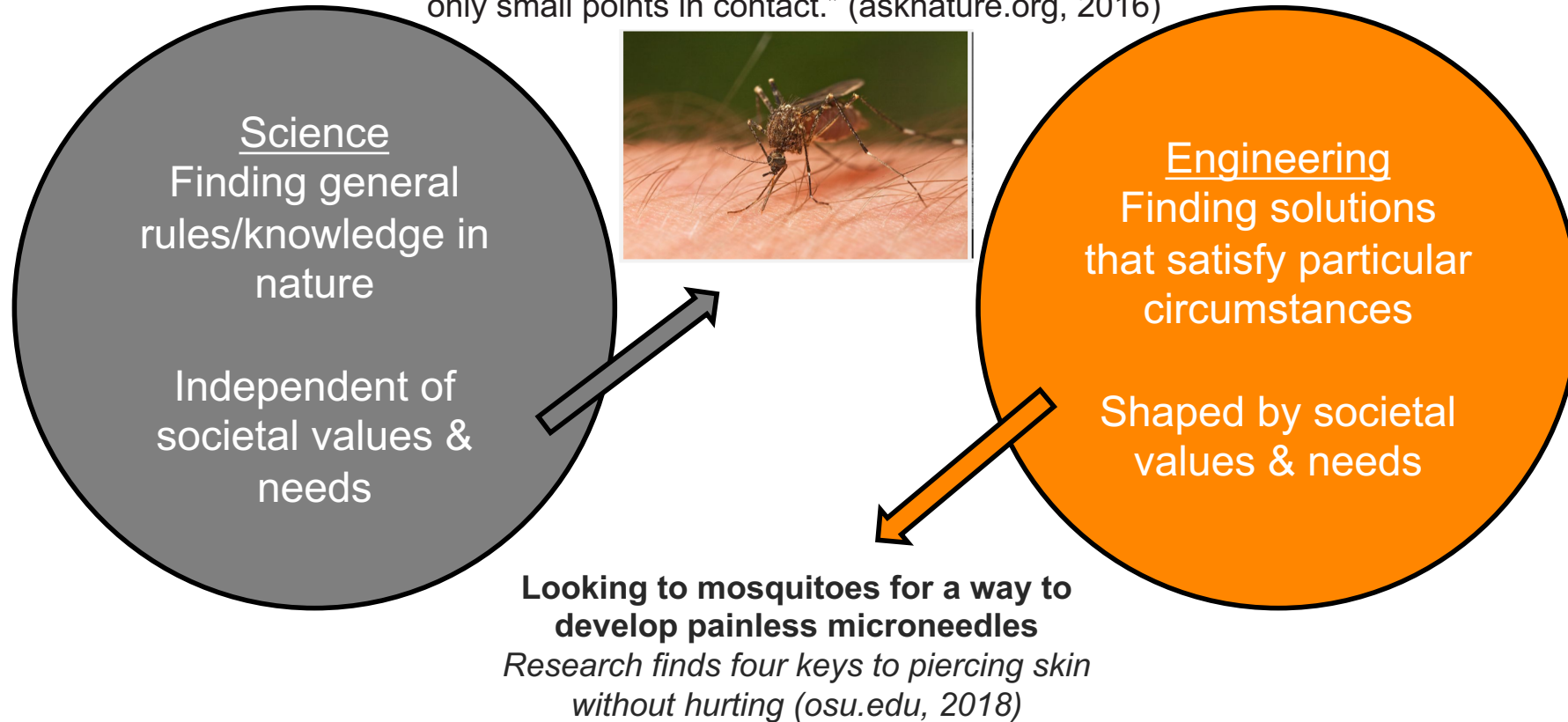
## Building Informed Designers

Patrick Herak, Sherri Youssef, Todd France, Bruce Wellman, & J. Blake Hylton

# Outline

- Engineering Design
- Scenario 1: Heartland Spaceport
  - Introduction to Needs Identification Canvas
  - Scoring the Needs Identification Canvas
  - How was it used with the Heartland Spaceport
- Scenario 2: MRI Machines
  - Revised: Opportunity Recognition Canvas
  - Stakeholder Profile Canvas
  - Using research to inform the solution
- References

# What is Engineering Design?

"The proboscis of the mosquito inserts painlessly because the jagged edge of the proboscis leaves only small points in contact." (asknature.org, 2016)



## Science
Finding general rules/knowledge in nature

Independent of societal values & needs

## Engineering
Finding solutions that satisfy particular circumstances

Shaped by societal values & needs

**Looking to mosquitoes for a way to develop painless microneedles**
*Research finds four keys to piercing skin without hurting (osu.edu, 2018)*

Engineering = application of math & science to solve problems

# Scenario 1: Heartland Spaceport

Imagine you are a professional engineer responsible for designing a spaceport near Kansas City…
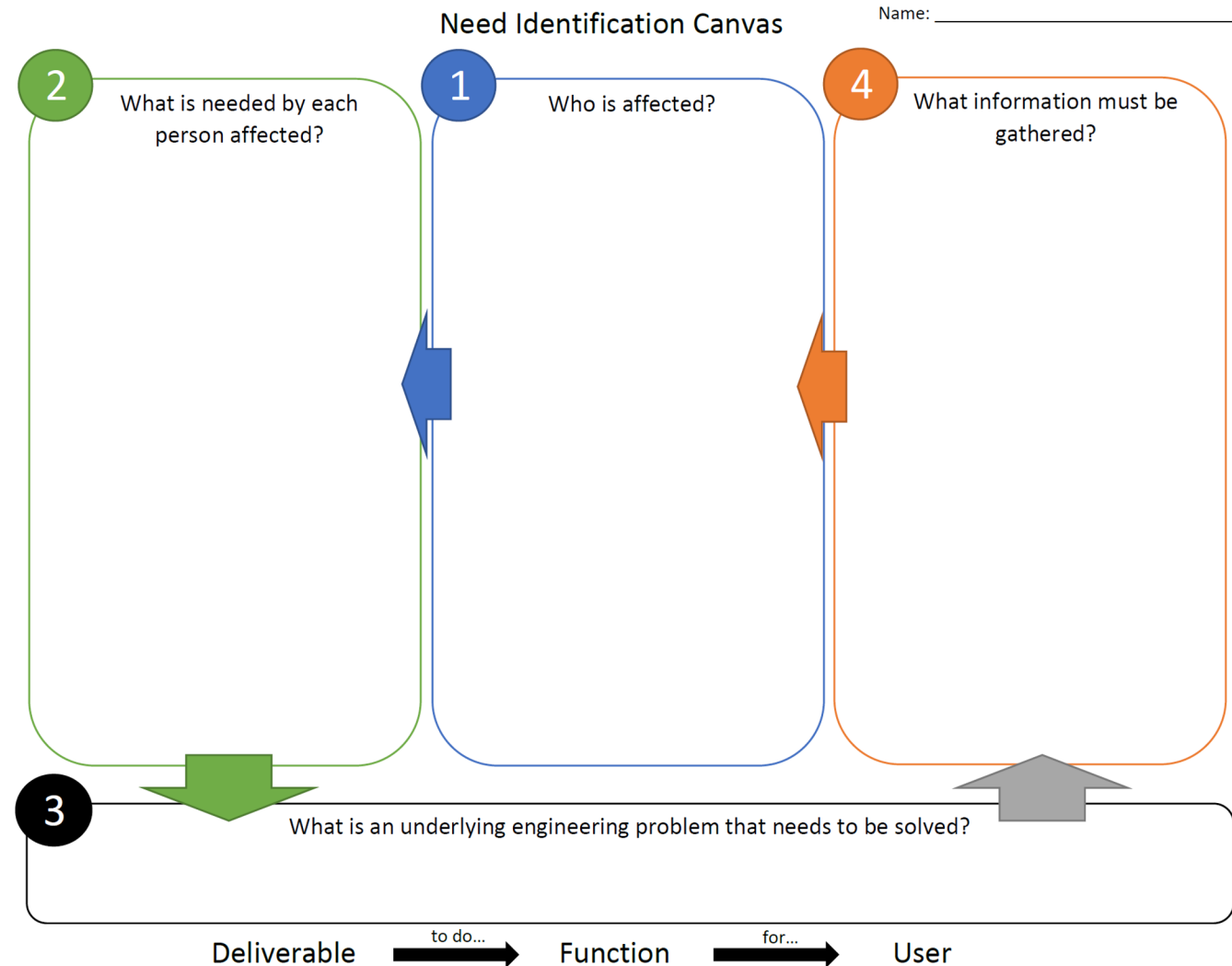


Photo: (Berger, E., 2018).



Photo: (Mexican, A.O., 2018)

# An introduction to an organizational tool to help us identify the needs of the people associated with a given problem.....

### Need Identification Canvas

Name: _____

**2** What is needed by each person affected?

**1** Who is affected?

**4** What information must be gathered?

**3** What is an underlying engineering problem that needs to be solved?

Deliverable → *to do...* → Function → *for...* → User

**2** What is needed by each person affected?

*… understand what people want…*

Identify the **need(s)** of the affected people
*Ask yourself: "If I were in their place, what would I want to be done about this?"*

**1** Who is affected?

*For a high-quality design, you must identify who is affected by the problem…*

List as many **affected people** as you can think of
*These can be individuals or groups*

**4** What information must be gathered?

*… and know what you need to find out.*

List as many **questions** as you can think of
*Answers to these should help you develop your solution*

**3** What is the underlying engineering problem that needs to be solved?

What is being produced? What purpose does it serve? Who receives it?

Deliverable → *to do…* → Function → *for…* → User

**Need Identification Canvas Rubric**

| | Beginning | Emerging | Developing | Informed Designer | Comments |
|---|---|---|---|---|---|
| **Stakeholders (1)** | Missing one or more type of stakeholder (user, direct, indirect) in those identified | Identified at least two stakeholders in at least two of the three stakeholder types | Identified at least two stakeholders in each of the three stakeholder types with at least eight total identified stakeholders, without duplicates | Identified at least two stakeholders in each of the three stakeholder types with at least ten total identified stakeholders, without duplicates | |

| | Beginning | Emerging | Developing | Informed Designer | Comments |
|---|---|---|---|---|---|
| **Stakeholder Needs (2)** *Connection Ratio (CR) = Connections/(Needs+ Stakeholders)* | Identifies some needs but not all stakeholders are considered CR = 0 -0.4 | Most stakeholders considered, some needs are superficial or invalid CR 0.3 - 0.6 | All stakeholders are considered, needs are fully developed but few connections across stakeholders identified CR 0.5 - 1.0 | All stakeholders are considered and fully developed, considering connections between stakeholders CR 0.8+ | |

| | Beginning | Emerging | Developing | Informed Designer | Comments |
|---|---|---|---|---|---|
| **Need Statement (3)** | One or more key elements (deliverable, function, user) missing | All key elements included but are weakly connected, too broad to be able to move forward | All key elements included and well connected but not sufficiently focused to be able to move forward | Need statement is concise and specific, explicitly connected, includes all key elements | |

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# Stakeholders

*The group of individuals who are or who could potentially be impacted by an engineering design solution for a particular issue*
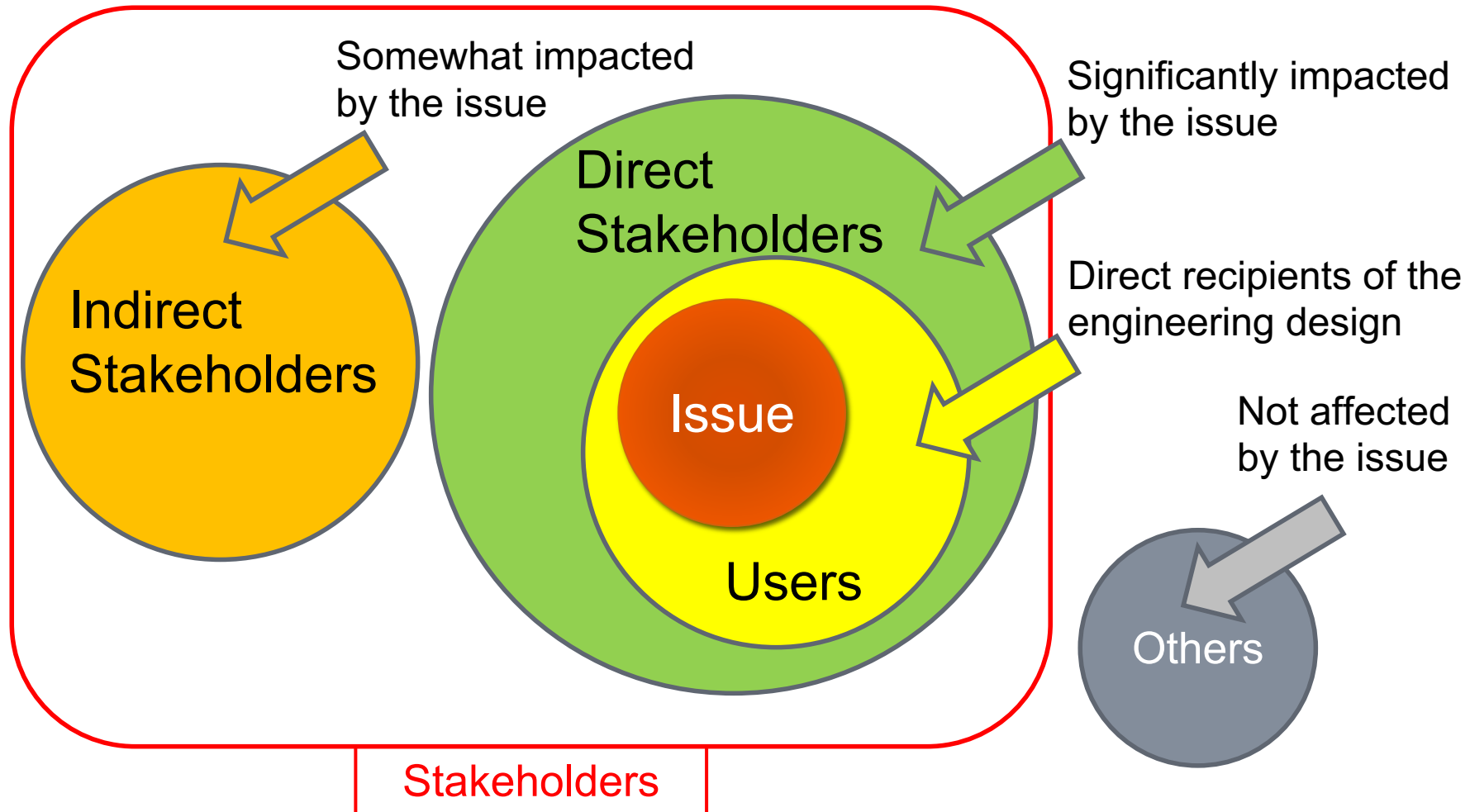
# Need statement

Discussion:

- *What need statement did you write?*

- *Did it identify the* *deliverable*, *its* *function*, *and the* *user*?

A possible need statement:

*"A consortium of companies and NASA would utilize a facility capable of launching spacecraft for communications satellites, scientific research, and space exploration."*

Fun fact: The Saturn V rockets which launched the Apollo moon missions were 363-ft tall and weighed 6.2 million pounds at lift-off! The SpaceX Falcon Heavy, the largest rocket in use today, is 230-ft tall and weighs only 3.1 million pounds.

## Need Identification Canvas
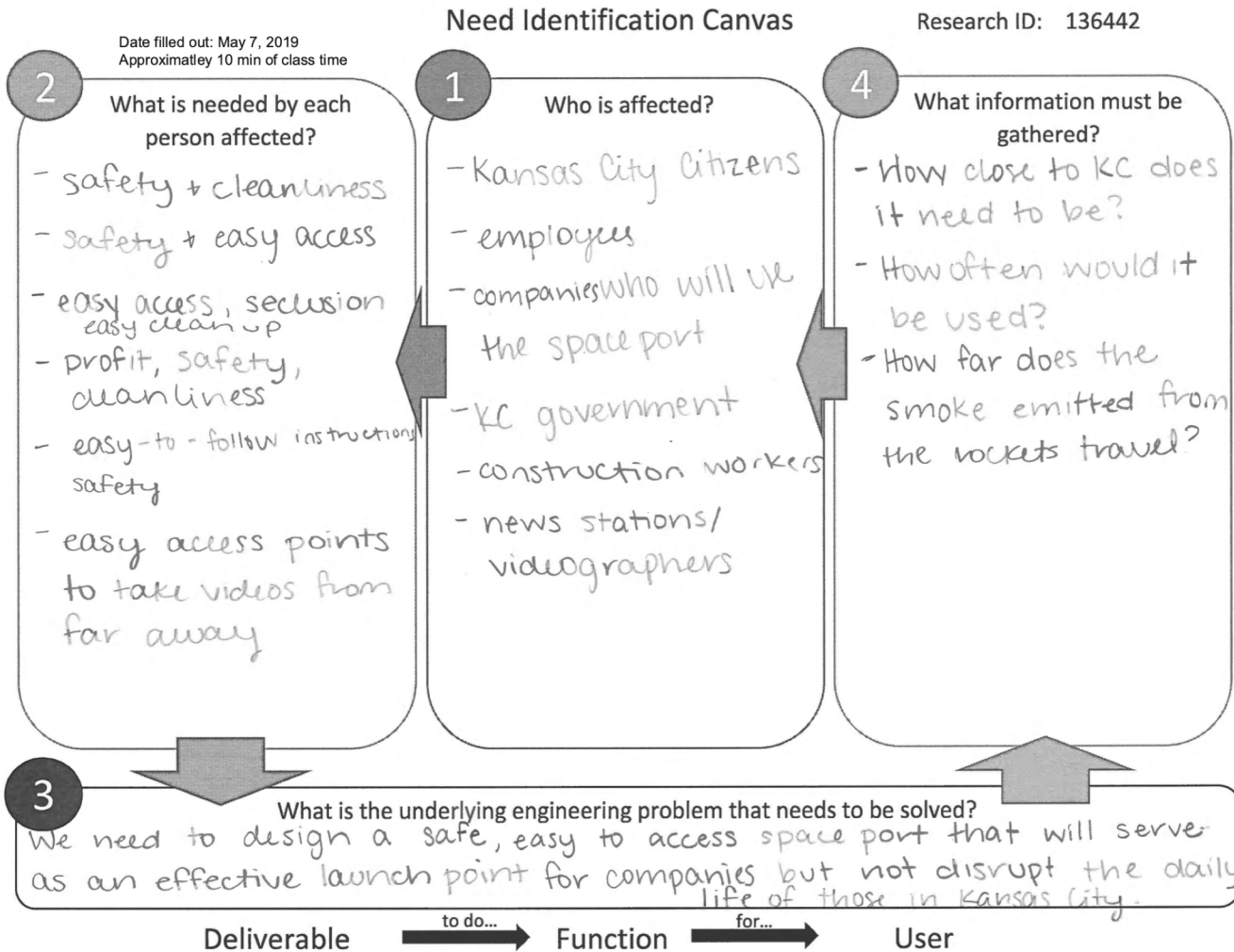
Date filled out: May 7, 2019
Approximatley 13 min of class time

Research ID: 124287

**2** What is needed by each person affected?

Support and involvement for the spaceport to be successful.

**1** Who is affected?
- engineers
- companies
- population
- govt
- state

**4** What information must be gathered?
- cost
- location
- availability of location

**3** What is the underlying engineering problem that needs to be solved?
What are the available locations for the spaceport?

Deliverable → to do... → Function → for... → User

### Need Identification Canvas Rubric

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**AVERAGE = 1.25**
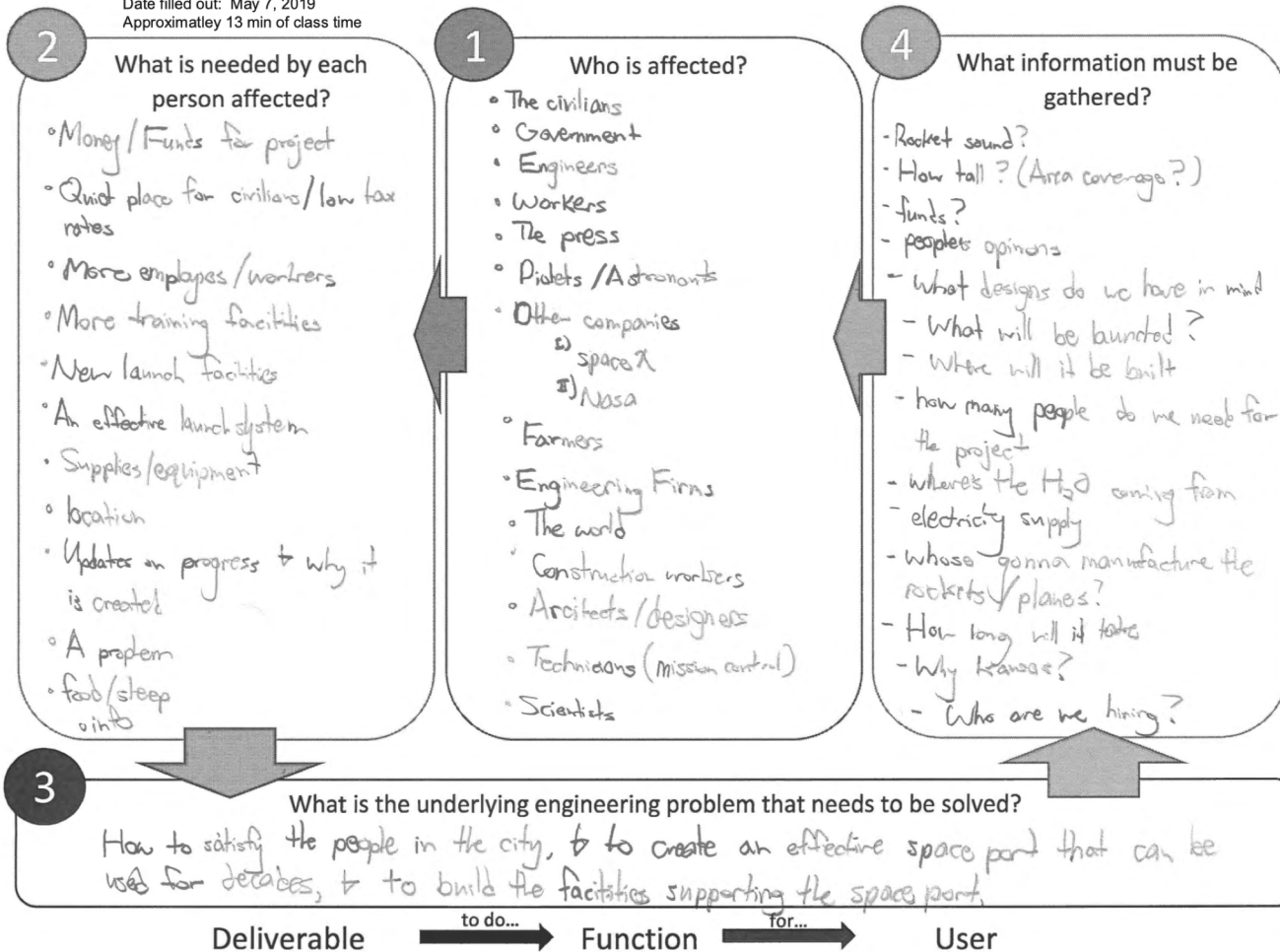
## Need Identification Canvas

Date filled out: May 7, 2019
Approximatley 10 min of class time

Research ID: 136442

**2 — What is needed by each person affected?**
- safety + cleanliness
- safety + easy access
- easy access, seclusion easy clean up
- profit, safety, cleanliness
- easy-to-follow instructions safety
- easy access points to take videos from far away

**1 — Who is affected?**
- Kansas City Citizens
- employees
- companies who will use the space port
- KC government
- construction workers
- news stations/ videographers

**4 — What information must be gathered?**
- How close to KC does it need to be?
- How often would it be used?
- How far does the smoke emitted from the rockets travel?

**3 — What is the underlying engineering problem that needs to be solved?**
We need to design a safe, easy to access space port that will serve as an effective launch point for companies but not disrupt the daily life of those in Kansas City.

Deliverable → to do... → Function → for... → User

## Need Identification Canvas Rubric

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## AVERAGE = 2.50

# Need Identification Canvas

Date filled out: May 7, 2019
Approximatley 13 min of class time
Research ID: 175659

**2 — What is needed by each person affected?**
- Money / Funds for project
- Quiet place for civilians / low tax rates
- More employes / workers
- More training facilities
- New launch facilities
- An effective launch system
- Supplies / equipment
- location
- Updates on progress & why it is created
- A problem
- food / sleep

**1 — Who is affected?**
- The civilians
- Government
- Engineers
- Workers
- The press
- peoples opinions
- Pilots / Astronauts
- Other companies
  - i) SpaceX
  - ii) Nasa
- Farmers
- Engineering Firms
- The world
- Construction workers
- Architects / designers
- Technicians (mission control)
- Scientists

**4 — What information must be gathered?**
- Rocket sound?
- How tall? (Area coverage?)
- funds?
- peoples opinions
- what designs do we have in mind
- What will be launched?
- Where will it be built
- how many people do we need for the project
- where's the H₂O coming from
- electricity supply
- whose gonna manufacture the rockets / planes?
- How long will it take
- Why kansas?
- Who are we hiring?

**3 — What is the underlying engineering problem that needs to be solved?**
How to satisfy the people in the city, & to create an effective space port that can be used for decades, & to build the facilities supporting the space port.

Deliverable → to do... Function → for... User

## Need Identification Canvas Rubric

| | Beginning | Emerging | Developing | Informed Designer |
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**AVERAGE = 3.25**

Mean and Standard Deviation of High School and First-Year Engineering Student scores on the NIC

(Herak, P. J., Wellman, B., France, T., West, M. E., & Hylton, J. B., 2020)
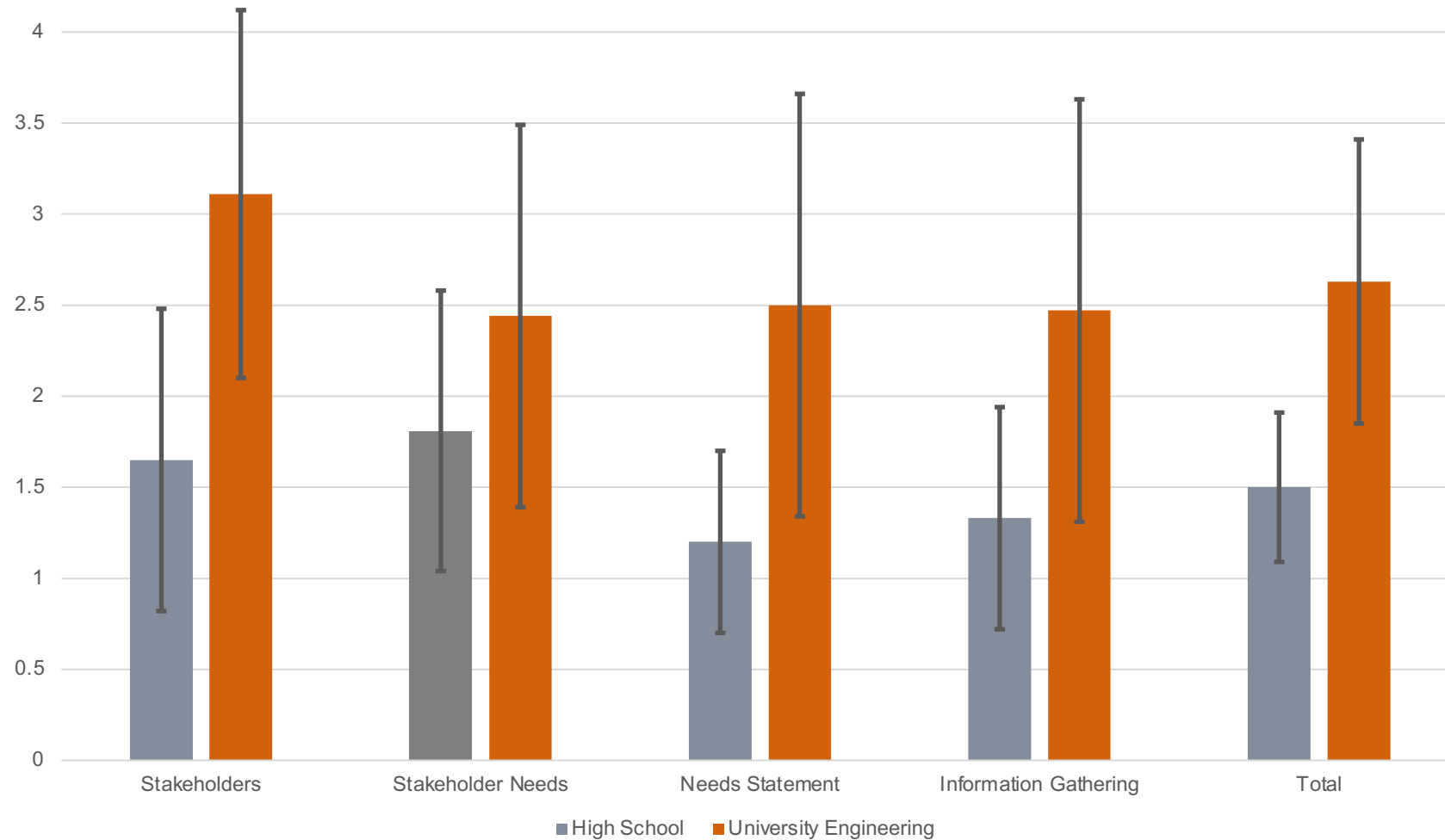
# Scenario 2: MRI machines

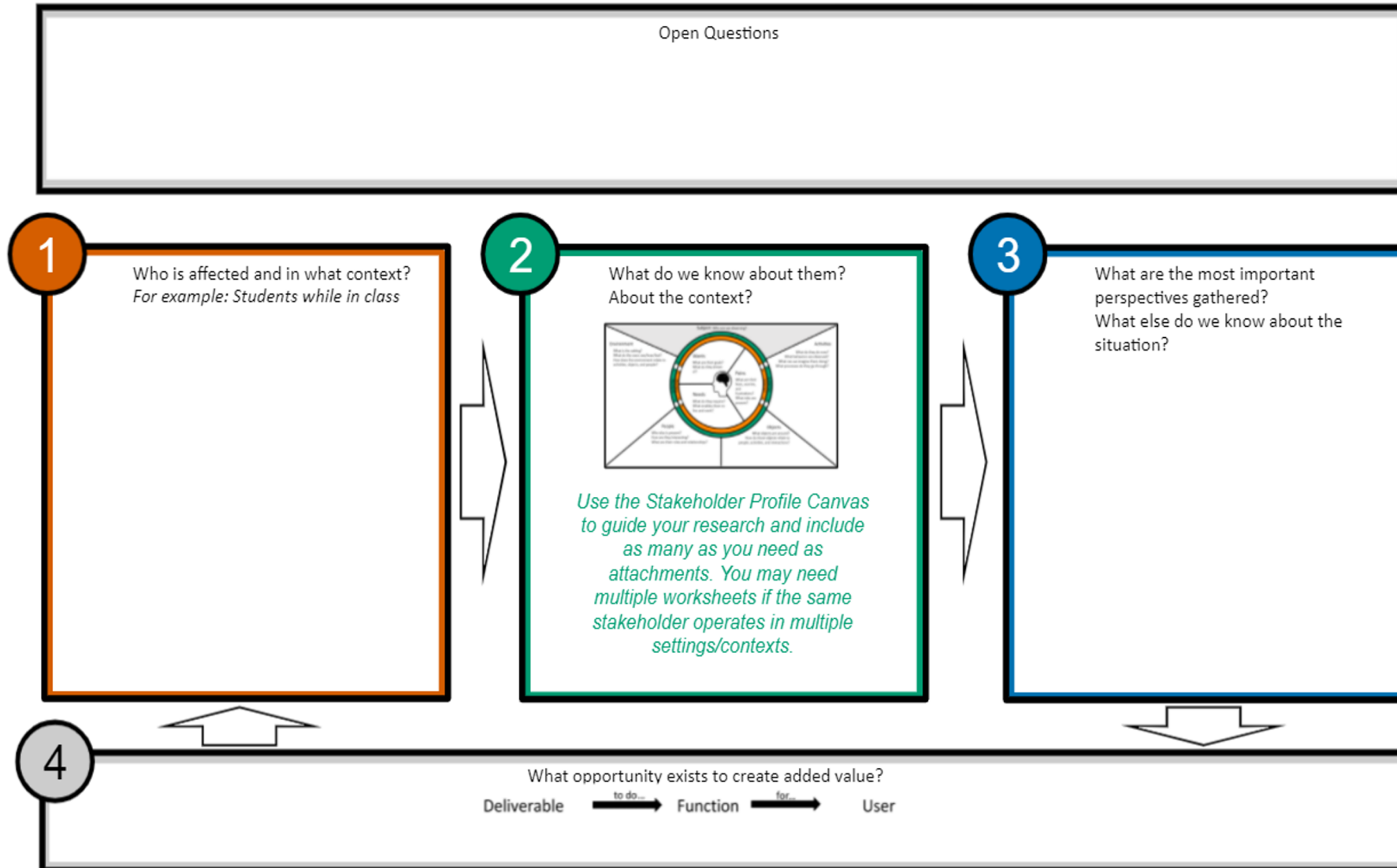Engineering = application of math & science to solve problems

Critical to understand the problem (and what's needed!)
BEFORE designing a solution

Issue

- Doctors at a given hospital were not getting good MRI images of young patients.

- MRI machines are strange, loud, and claustrophobic

- *What is the underlying problem?*

# New: Opportunity Recognition Canvas

Open Questions

**1** Who is affected and in what context?
*For example: Students while in class*

**2** What do we know about them?
About the context?



*Use the Stakeholder Profile Canvas to guide your research and include as many as you need as attachments. You may need multiple worksheets if the same stakeholder operates in multiple settings/contexts.*

**3** What are the most important perspectives gathered?
What else do we know about the situation?

**4** What opportunity exists to create added value?

Deliverable → *to do...* → Function → *for...* → User
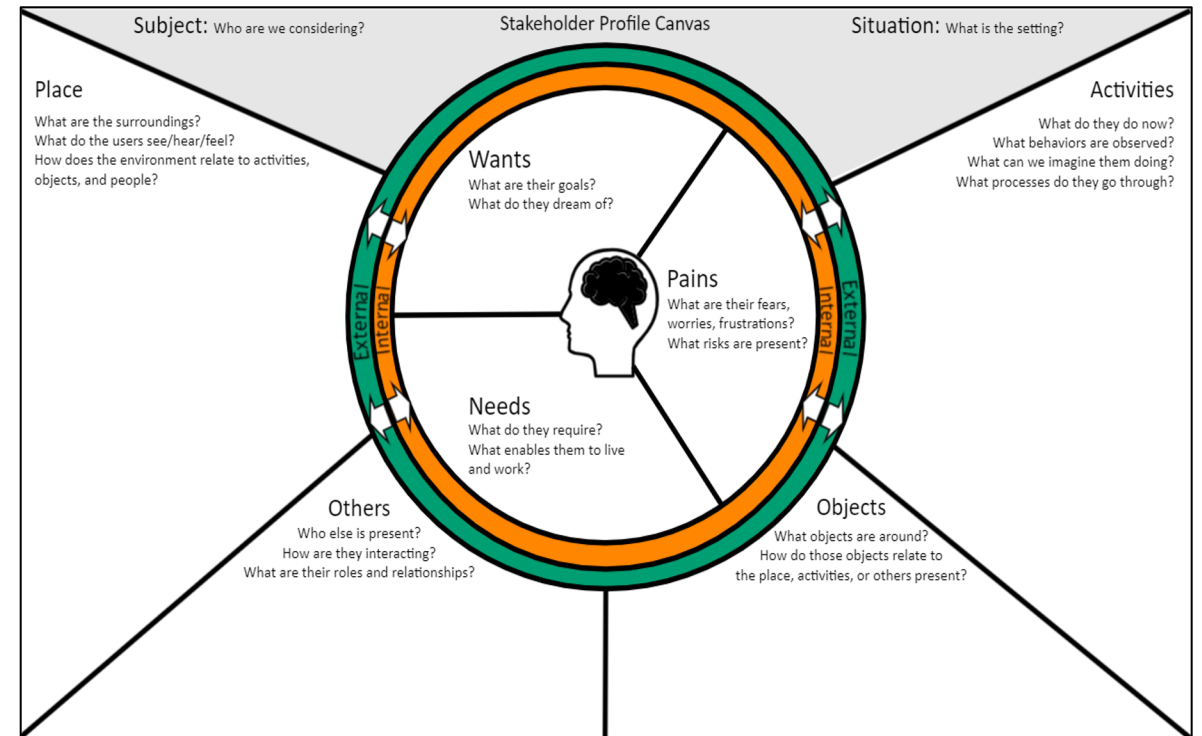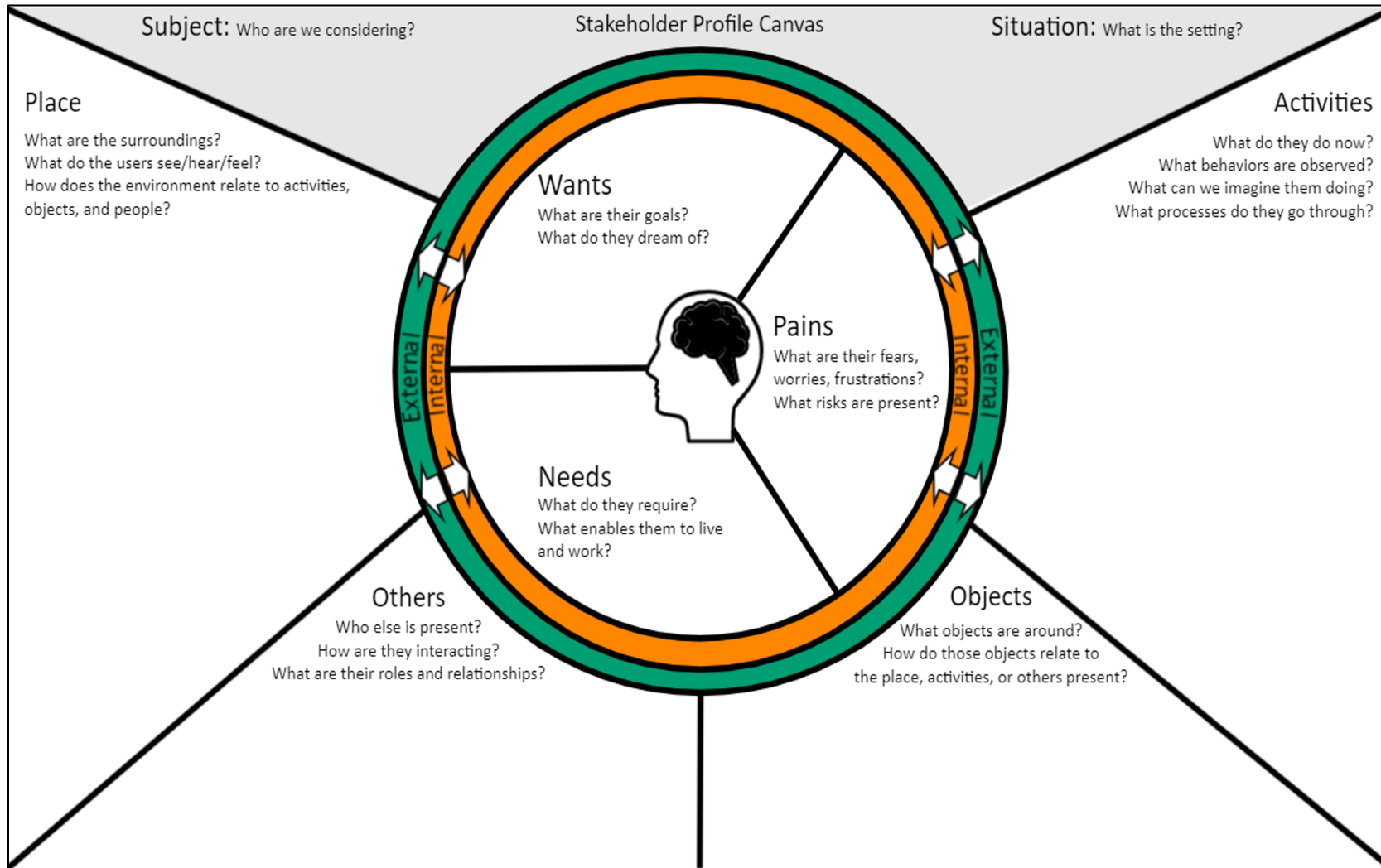
# New: Stakeholder Profiles

- Consider your stakeholders and identify the 2-3 **most important** based on your ratings

- For each of those most important stakeholders, complete a **Stakeholder Profile Canvas**

- Considering what you've gathered, identify the information which you feel is most important and list/summarize this information in the Box 3 of the **Opportunity Recognition Canvas**

- Add any additional information to Box 3 that you feel is important about the situation at hand but not otherwise captured



Because this is a somewhat abbreviated design experience, try not to dwell too long on any one stakeholder. Get enough down that you have something to move forward with and then move on.

# New: Stakeholder Profile Canvas



Stakeholder Profile Canvas

Subject: Who are we considering?

Situation: What is the setting?

Place
What are the surroundings?
What do the users see/hear/feel?
How does the environment relate to activities, objects, and people?

Activities
What do they do now?
What behaviors are observed?
What can we imagine them doing?
What processes do they go through?

Wants
What are their goals?
What do they dream of?

Pains
What are their fears, worries, frustrations?
What risks are present?

Needs
What do they require?
What enables them to live and work?

External    Internal

Others
Who else is present?
How are they interacting?
What are their roles and relationships?

Objects
What objects are around?
How do those objects relate to the place, activities, or others present?

# New: Evaluating Stakeholders

- Three dimensions of importance:
  - **Severity**: How significantly are they are affected by the result
  - **Utility**: To what extent do our design choices depend on their input
  - **Capability**: To what extent are we able to obtain their feedback



## MRI Examples:

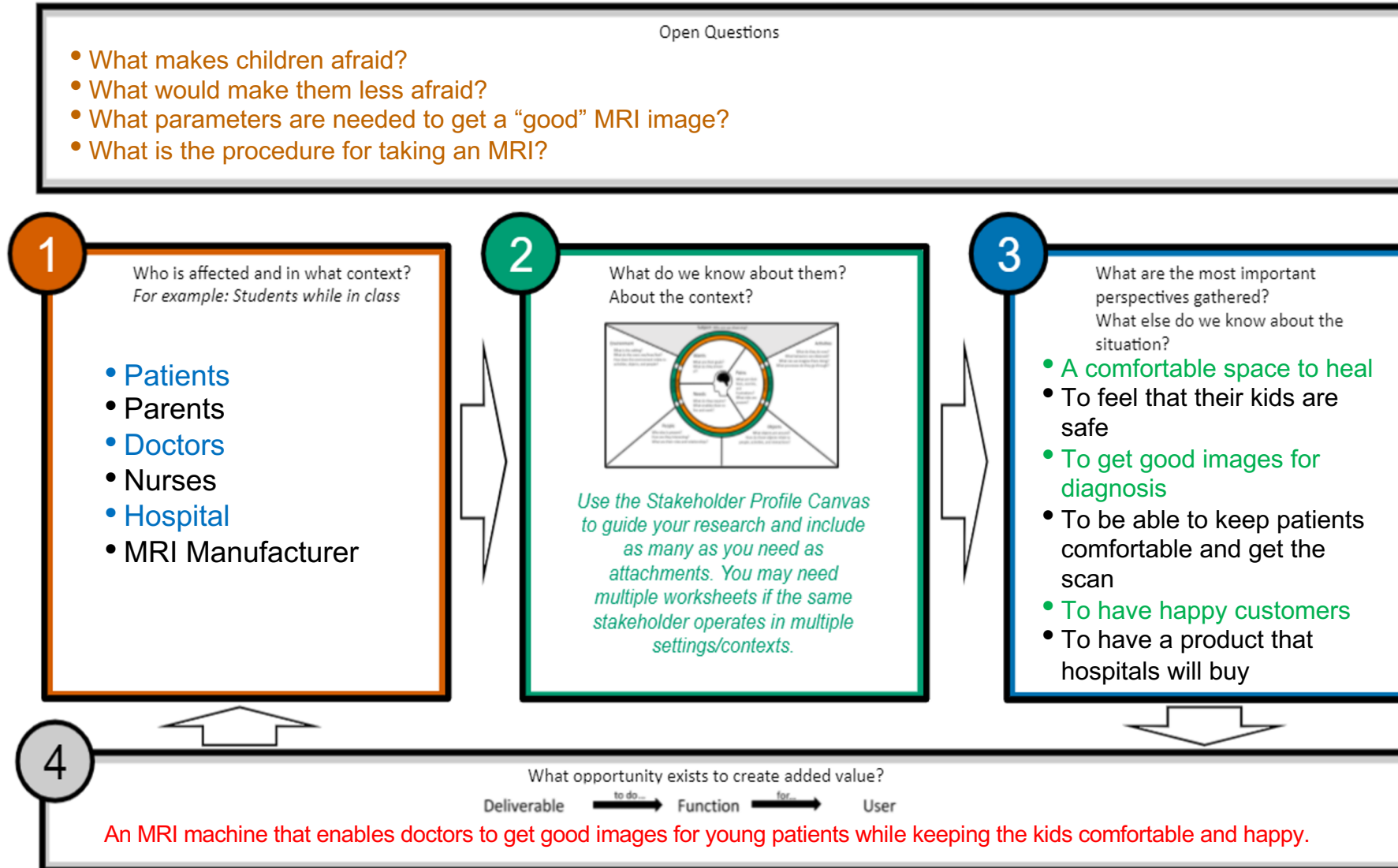| Stakeholder | Severity | Utility | Capability |
|---|---|---|---|
| Kids | H | H | M |
| Parents | | | |
| Doctors | How would you rate the rest of these stakeholders? | | |
| Technicians | | | |
| Competition | | | |

# Review: Needs

**Need Finding** *verb*:

The act of considering the specific requirements and desires of a diverse set of individuals and groups to frame what your design should accomplish.

Young Patients

Hospital

Medical Techs

Doctors

MRI Manufacturer

Parents

# New: Opportunity Recognition Canvas

**Open Questions**
- What makes children afraid?
- What would make them less afraid?
- What parameters are needed to get a "good" MRI image?
- What is the procedure for taking an MRI?

**1** Who is affected and in what context?
*For example: Students while in class*

- Patients
- Parents
- Doctors
- Nurses
- Hospital
- MRI Manufacturer

**2** What do we know about them? About the context?



*Use the Stakeholder Profile Canvas to guide your research and include as many as you need as attachments. You may need multiple worksheets if the same stakeholder operates in multiple settings/contexts.*

**3** What are the most important perspectives gathered? What else do we know about the situation?

- A comfortable space to heal
- To feel that their kids are safe
- To get good images for diagnosis
- To be able to keep patients comfortable and get the scan
- To have happy customers
- To have a product that hospitals will buy

**4** What opportunity exists to create added value?

Deliverable → to do... → Function → for... → User

An MRI machine that enables doctors to get good images for young patients while keeping the kids comfortable and happy.

# Problem Framing helps inform the Solution

*How do we make sure that what we produce is actually solving a need?*



MRI Solution

- Problem ≠ too loud/small
- Problem = too scary
- Need = presenting a safe, calm experience for kids, not decreasing noise
- *Not thinking about the problem in advance can lead you down the wrong solution path!*

# References

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