Changes in pre-service teacher understanding of STEAM inquiry

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Introduction

Inquiry shown to be highlight effective

BUT

Is seldom integrated into current teaching practice

What kind of scaffolds, supports and structures are required so that inquiry can be incorporated into teaching practice?

Research overview

2016	2017	2018	2019	2020	2021	
2 sites (10 weeks) GC - Secondary - free choice MG – Primary (3 projects) - set choice	1 site (7 weeks) Primary (4 projects) Secondary (2 projects)	1 site Secondary (7 and 8) 2 Year 7 classes – free choice 2 Year 8 classes – free choice STEM excellence class 8 weeks	1 site Secondary (7 and 8) 3 Year 7 classes – set choice 3 Year 8 classes – free choice STEM excellence class 8 weeks	COVID	1 site Secondary (7 and 8) 3 Year 7 classes – set choice 3 Year 8 classes – free choice STEM excellence class 10 weeks	3 sites (2 Oncampus, 1 online) XX science pre-service teachers XX weeks
Paper journal	Paper journal	PowerPoint journal	OneNote journal		OneNote journal	OneNote journal
After school	After school	In class	In class		In class	In class

The iterative nature of design based methodology was used to develop, test and refine the model in a variety of contexts

Theoretical basis

- Why STEAM and not STEM?
- How is STEAM conceptualised?
- How is it operationalised in the classroom?

Our conceptual framing paper is downloadable

The STEM definition crisis – acronym madness

Other variations

- STM (Scientific, Technical, and Mathematics;[10] or Science, Technology, and Medicine; or Scientific, Technical, and Medical)
- eSTEM (environmental STEM)[11][12]
- STEMIE (Science, Technology, Engineering, Mathematics, Invention and Entrepreneurship); adds Inventing and Entrepreneurship as means to apply STEM to real world problem solving and markets.[13]
- iSTEM (invigorating Science, Technology, Engineering, and Mathematics); identifies new ways to teach STEM-related fields.
- STEMLE (Science, Technology, Engineering, Mathematics, Law and Economics); identifies subjects focused on fields such as applied social sciences and anthropology, regulation, cybernetics, machine learning, social systems, computational economics and computational social sciences.
- MEd Curriculum Studies: STEMS²[14] (Science, Technology, Engineering, Mathematics, Social Sciences and Sense of Place); integrates STEM with social sciences and sense of place.
- METALS (STEAM + Logic),[15] introduced by Su Su at Teachers College, Columbia University.[citation needed]
- STREM (Science, Technology, Robotics, Engineering, and Mathematics); adds robotics as a field.
- STREM (Science, Technology, Robotics, Engineering, and Multimedia); adds robotics as a field and replaces mathematics with media.
- STREAM (Science, Technology, Robotics, Engineering, Arts, and Mathematics); adds robotics and arts as fields.
- STEAM (Science, Technology, Engineering, Arts, and Mathematics)[16]
- A-STEM (Arts, Science, Technology, Engineering, and Mathematics);[17] more focus and based on humanism and arts.
- STEAM (Science, Technology, Engineering, Agriculture, and Mathematics); add Agriculture.
- STEAM (Science, Technology, Engineering and Applied Mathematics); more focus on applied mathematics[18]
- GEMS (Girls in Engineering, Math, and Science); used for programs to encourage women to enter these fields.[19][20]
- STEMM (Science, Technology, Engineering, Mathematics, and Medicine)
- AMSEE (Applied Math, Science, Engineering, and Entrepreneurship)
- THAMES (Technology, Hands-On, Arts, Mathematics, Engineering, Science)
- THAMES (Technology, Humanities, Arts, Mathematics, Engineering, and Science; includes all three branches of science: natural science, social science, and formal science)
- MINT (Mathematics, Informatics, Natural sciences and Technology)

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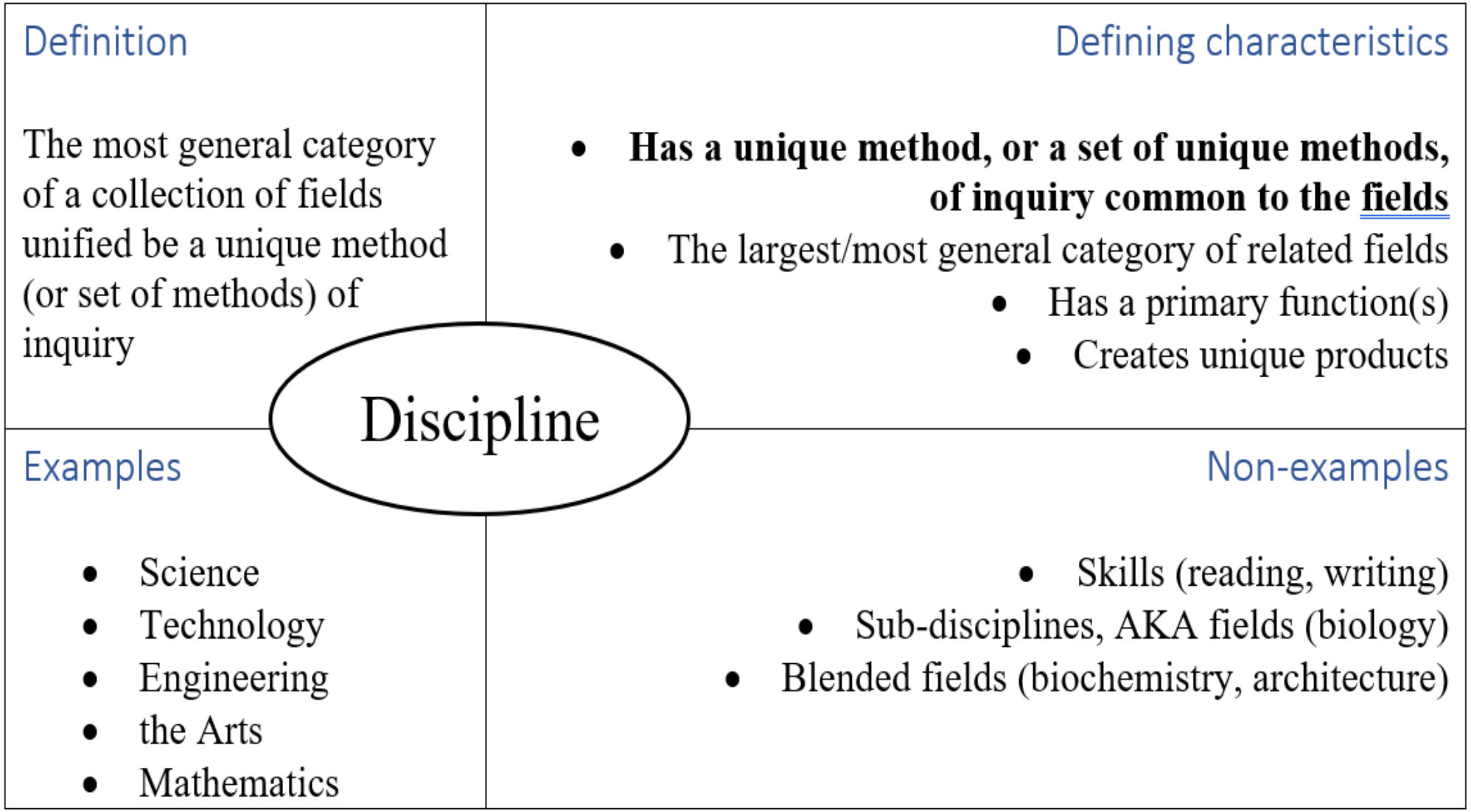
Employing the Frayer model to define Discipline



Inclusion criteria

The discipline must have…

1. A primary function(s)
2. Epistemology, ontology and praxis
3. Clearly defined products
4. Key point of difference from other disciplines

Exclusion criteria

Things not included are…

Skills (e.g., reading, graphing)

School subjects (e.g., the school subjects of science, mathematics, history, HPE)

Nature of the work (e.g., hands-on, invention, entrepreneurship, invigorating)

Particular focus (e.g., environmental)

The STEAM fields have a primary function

Discipline	Methods, processes, practices (praxis)	Primary function(s)	Products	School subjects	Professions
Sciences (social and natural)	The scientific methods (experimental, descriptive, modelling, theoretical) The humanistic methods (e.g., hermeneutics, semiotics, historical methods, narrative inquiry etc.)	Exploring the natural universe, Knowledge generation	Hypotheses, theories, truth	Biology Chemistry Physics Psychology Marine studies History Geography Economics	Medical doctors Ecologists Industrial chemists Astrophysicists Historians Geographers Economists
Technology	The technology process	Problem solving, creating solutions	Physical/concrete products (e.g., cars, computers, hammers) Abstract products (e.g., laws, protocols etc.)	Design Fashion Food & Nutrition Hospitality ICT	Inventors Roboticists Fashion designers Computer programmers Architect
Engineering	The engineering process			Engineering Engineering skills	Civil engineers Mechanical engineers Chemical engineers Electrical engineers
the (creative) Arts	The artistic methods (e.g., Studio Habits of Mind), arts-based inquiry	1. Knowledge storage and dissemination 2. Exploring the… a) human condition b) 'what if' c) aesthetic	Sculptures, paintings, literature, journal articles, plays, movies, TV shows, fashion, songs, dance	Literature studies Music Dance Media Arts Visual Art Drama	Musicians Actors Painters Writers
Mathematics	Proofs, Polya's problem solving method, mathematical modelling	Exploring the abstract Discovering and encoding patterns	Axioms, theorems, proofs, Truth	Algebra Geometry Calculus	Actuaries Economists Statisticians Mathematical modelers

STEAM

The inquiry tools we give students to

ANSWER questions
SOLVE problems
CREATE products

to make a difference in their lives or the lives of others

RSITY

The STEAM fields work synergistically

Science

Technology

Engineering

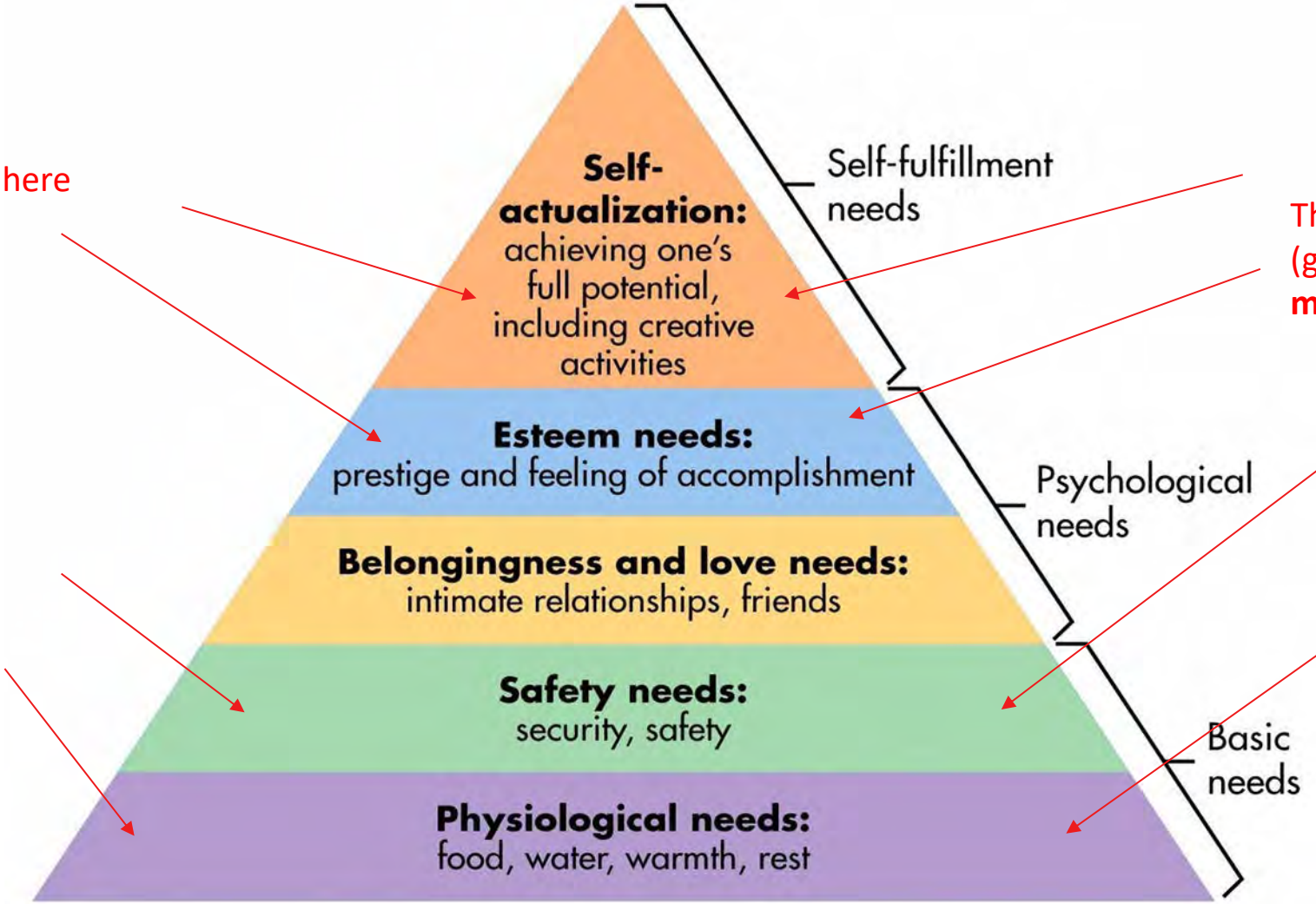
the Arts

Mathematics

The STEAM fields are about meeting human needs

The Arts lives here

The domain of **Technology** and **engineering**

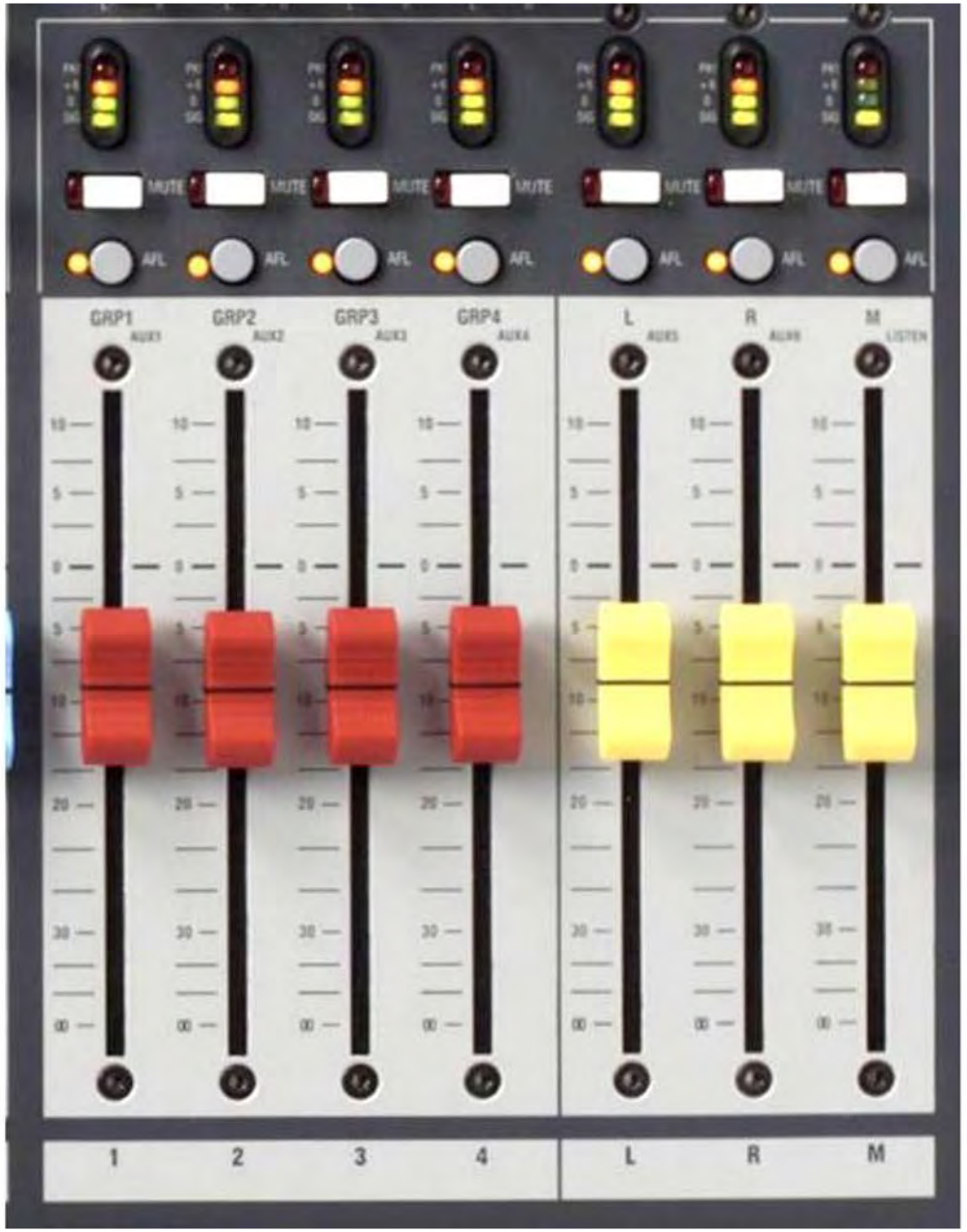


Through answering questions (gaining knowledge), **science** and **maths** helps meet these needs

Maslow's needs hierarchy

The vast majority of STEAM projects will draw upon more than one field

- How much money will the school make if we cover all the rooves with solar panels?
- How can we help to maintain the back creek and monitor platypus numbers?
- Can drones be used to look out for sharks and keep swimmers safe?

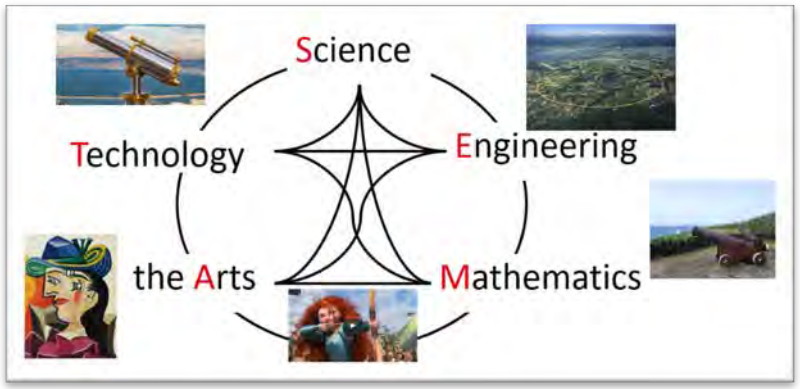


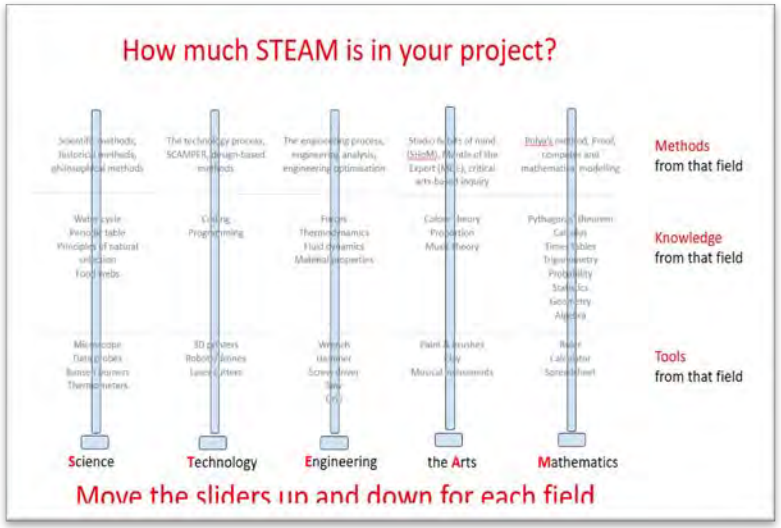
The STEAM inquiry model and the STEAM sliders

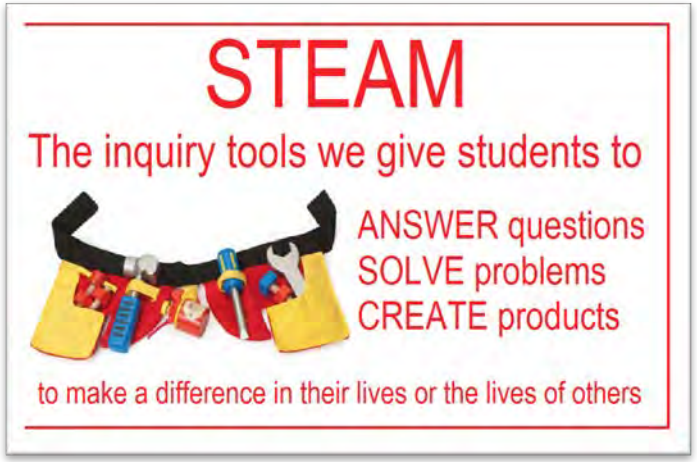
are a tool

for students, teachers and researchers

to think about **inter-, multi- and trans- disciplinarity**







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Research questions

How accurately can pre-service teachers assess the amount of STEAM in their projects?

Is this impacted by participating in an inquiry unit?

How useful do pre-service teachers perceive the STEAM inquiry model for their future teaching?

Method: the course

Week	Lab topic
1	Lab orientation
2	Pendulum swing (Physical sciences)
3	Water's heating curve (Chemical sciences)
4	Indigenous seasons (Indigenous sciences, Earth and Space sciences)
5	Osmosis and microscopy (Biological sciences)
6	Independent STEAM project (inspiration, planning)
7	Independent STEAM project (conducting)
8	Independent STEAM project (analysing, reporting)

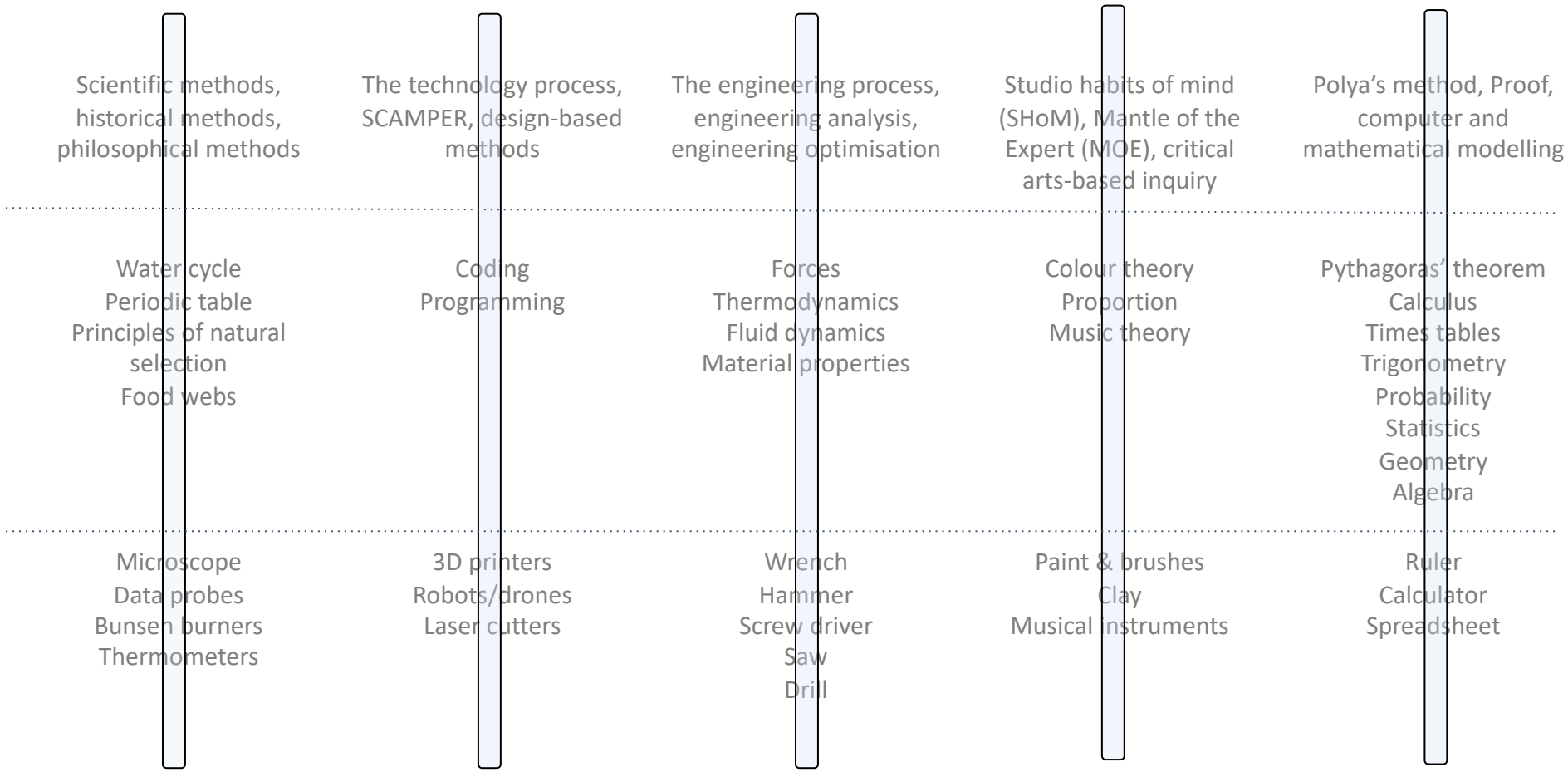
Structure of the Independent STEAM project:

1. Planning week – focus on research question, background research, identifying variables, hypothesis construction, having a play with the
2. Conducting week – data collection
3. Analysing and reporting week – data analysis, report writing

Method: participants

- Pre-service teachers with a senior science teaching area:
    - biology
    - chemistry
    - physics
    - psychology
- Undergrad (n = XX) and postgrad (n = XX)
- Undergrads – in Trimester 1 of their 2nd year
- Postgrads – in Trimester 1 of their 1st year
- 14 pre-service teachers participated in the research

AFTER: How was STEAM addressed in your inquiry?



I use processes from this discipline in my inquiry

I recall knowledge from this discipline in my inquiry

I use tools from this discipline in my inquiry

Science **T**echnology **E**ngineering the **A**rts **M**athematics

Move the sliders up and down for each field

Screen shot of the OneNote notebook

6-8 Independent STEAM project

Thursday, January 14, 2021 11:24 AM

Design, conduct and report on either a science experiment or a technology/design project to 'create the BEST whirly bird OR the BEST paper plane launcher'. Your tutor will walk you through the report writing process for a technology/design project.

Causes and effects table

Causes (IV and CVs)	Effects (DV)

Research question and hypothesis

General question	What and how do the factors related to pendulums effect its period?
Specific research question	What is the effect of varying the string length on the period of a pendulum?
IF	We increase the string length
THEN	the period will _____ (increase/decrease/stay the same)
WHEN	
BECAUSE	

Risk assessment

Hazard	Risks	Mitigation strategy
Harm to self		
Harm to others		
Harm to equipment and property		
Harm to the environment		

Materials and equipment

<take a photo of the equipment and materials. Insert here and use text boxes to label it. Make it insta-worthy>

Method

<agentless, past tense, passive voice>

Results

<insert titled and labelled photos>
<insert graph here, raw results table goes in the appendix>

Discussion

The hypothesis <copy and paste hypothesis> was supported/rejected by the data.

Issue with the practical	How to fix it

Conclusion

The hypothesis <copy and paste hypothesis> was supported/rejected by the data.

Things future studies should explore	Justification

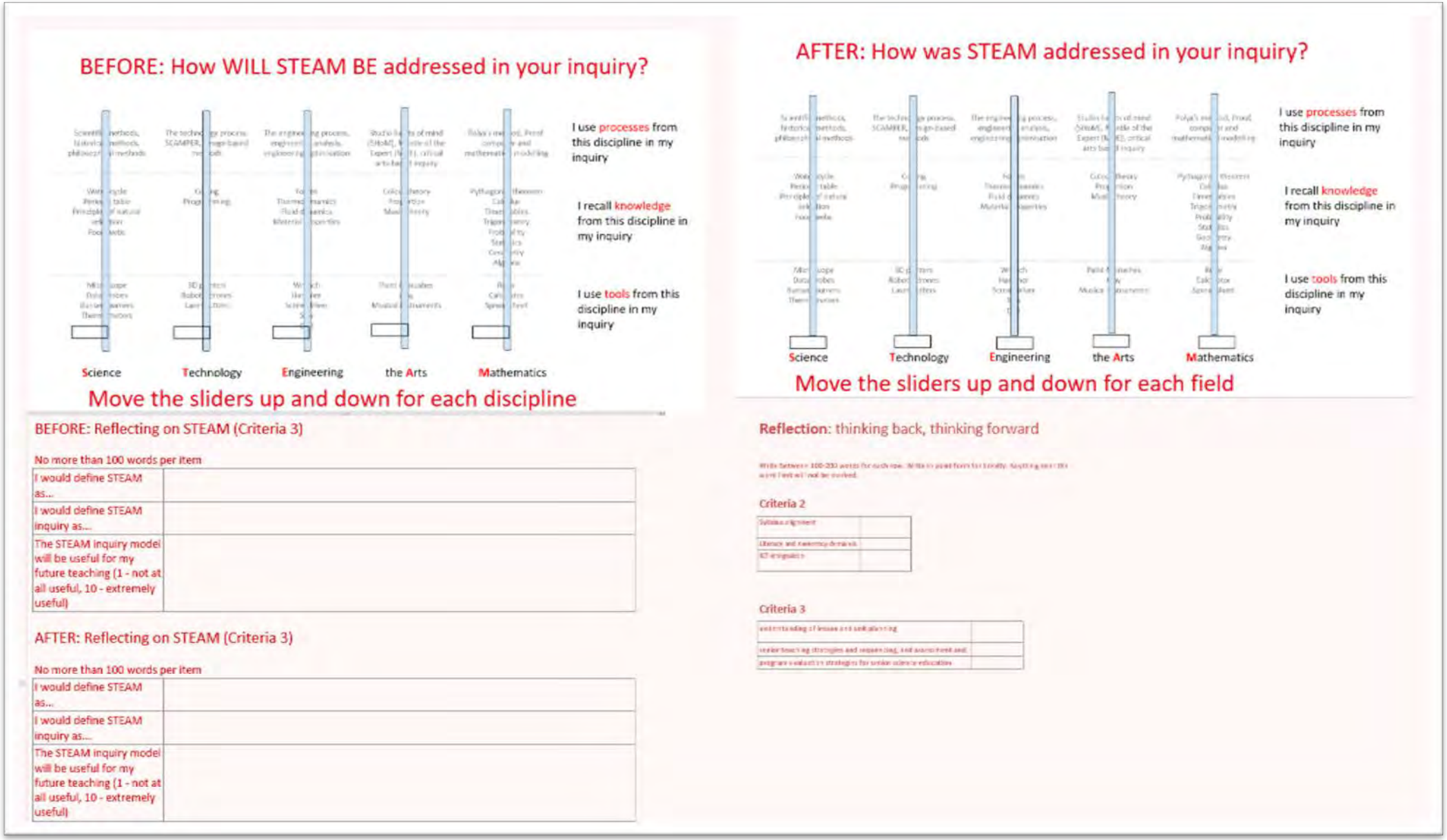
Appendix

<insert raw data tables here>

How to make a paper helicopter that flies

Paper Plane Launcher | Paper Plane | How to Make Paper Plane | Origami Paper Plane | Mad Times

Screen shot of the OneNote notebook



BEFORE: How WILL STEAM BE addressed in your inquiry?

I use processes from this discipline in my inquiry

I recall knowledge from this discipline in my inquiry

I use tools from this discipline in my inquiry

Science Technology Engineering the Arts Mathematics

Move the sliders up and down for each discipline

AFTER: How was STEAM addressed in your inquiry?

I use processes from this discipline in my inquiry

I recall knowledge from this discipline in my inquiry

I use tools from this discipline in my inquiry

Science Technology Engineering the Arts Mathematics

Move the sliders up and down for each field

BEFORE: Reflecting on STEAM (Criteria 3)

No more than 100 words per item

I would define STEAM as...	
I would define STEAM inquiry as...	
The STEAM inquiry model will be useful for my future teaching (1 - not at all useful, 10 - extremely useful)	

AFTER: Reflecting on STEAM (Criteria 3)

No more than 100 words per item

I would define STEAM as...	
I would define STEAM inquiry as...	
The STEAM inquiry model will be useful for my future teaching (1 - not at all useful, 10 - extremely useful)	

Reflection: thinking back, thinking forward

Criteria 2

Criteria 3

Example lab report

6-8 Independent STEAM project

Design, conduct and report on either a science experiment or a technology/design project to 'create the BEST whirly bird OR the BEST paper plane launcher'. Your tutor will walk you through the report writing process for a technology/design project.

Causes and effects table

highlight

Causes (IV and CVs)	Effects (DV)
Weight of strip (CV)	Flight time (DV)
Position of weight (on paper) (CV)	How quickly the whirly bird spins (DV)
Location (air density of locale) (CV)	
Paper size (using A-no) (IEV)	
Number of wings (CV)	
Colour (CV)	

Research question and hypothesis

General question	What and how do the factors related to paper affect the flight time
Specific research question	What is the effect of paper weight on the flight time of a whirley bird from a 3.1M height.
IF	The paper is heavier
THEN	The period of the flight time will be less than if the paper was lighter
WHEN	Weight is removed from the paper, the period will be longer
BECAUSE	Due to air resistance and drag forces that are in opposition to the relative motion of an object as it travels through air (Universe Today, N.D)

Risk assessment

Hazard	Risks	Mitigation strategy
Harm to self	• Paper cuts	• General warning about paper and reiteration of safety rules
Harm to others	• Eye injury	• safety goggles
Harm to equipment and property	• Breaking scissors	• use equipment correctly
Harm to the environment	• paper wastage	• Recycle paper

Materials and equipment

Figure 1

Equipment used for whirley bird experiment

Note: iPhone was used to capture this photo, and acted as a stopwatch.

Method

Step 1: Materials were gathered as per figure 1

Step 2: Whirley bird was constructed based upon Suartbb's YouTube video, *How to make a paper helicopter that flies* (Suartbb, 2015, 3:13)

Step 3: Once complete, the whirley bird was released from a 3.1m heighted staircase

Step 4: Whirley bird was released 10 times, for each series.

Step 5: Results were recorded in excel (see appendix 1)

Figure 2

Whirley bird used in experiment with 2 paper clips demonstrated

Results

Figure 3

Average flight time (seconds) of whirly bird at varying weights

Discussion

Measurement of cuts	• Using a rule to create an exact measurements and even opportunities for each side
Inconsistency with the time keeper and person releasing the whirley bird	• Having the same person as time keeper and the same person releasing the whirley bird would prevent this
Number of whirley birds used	• This practical only used the one whirley bird, as opposed to others. This may have skewed the results due to impact the paper may have had collected towards the 40th time.

LOL

Conclusion

Things future studies should explore	Justification
• Wing span size	• Future studies should investigate the difference of wing spans i.e., A4 and A3 paper to determine if this has an effect on flight time.
• Number of wings	• Future studies should investigate the number of wings on the whirley bird. If a higher number of wings were present, would this make the whirley bird go faster due to a decreased drag in air resistance (Universe Today, N.D).
• Thickness of paper	• Future studies should investigate the difference in outcomes based upon thickness of paper. i.e., the use of cardboard in comparison to butchers paper and tissue paper.
• Location	• Future studies should investigate how the location impacted the results. Future studies should be conducted outside to gain a greater understanding of this variable.

go more into the why

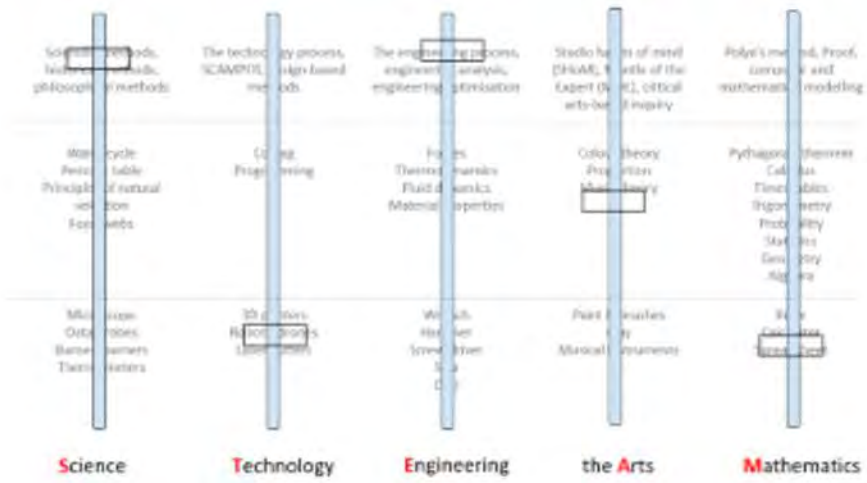
Appendix

Table 1

Raw data for experiment

Number of Paper Clips	zero	one	two
Average flight time (s)	1.729	1.587	1.743
1	2.05	1.25	1.58
2	2.57	1.7	1.53
3	1.97	1.3	1.9
4	1.2	1.52	1.99
5	1.25	1.39	1.72
6	1.43	1.34	1.93
7	1.38	1.63	1.74
8	1.52	1.6	1.7
9	1.5	1.9	1.78
10	2.02	2.24	1.56
Sum	1.729	1.587	1.743

BEFORE: How WILL STEAM BE addressed in your inquiry?



I use processes from this discipline in my inquiry

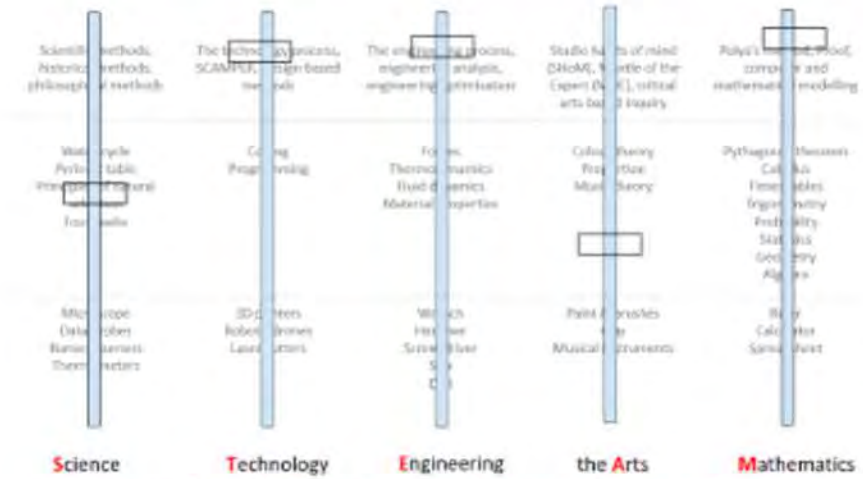
I recall knowledge from this discipline in my inquiry

I use tools from this discipline in my inquiry

Science Technology Engineering the Arts Mathematics

Move the sliders up and down for each discipline

AFTER: How was STEAM addressed in your inquiry?



I use processes from this discipline in my inquiry

I recall knowledge from this discipline in my inquiry

I use tools from this discipline in my inquiry

Science Technology Engineering the Arts Mathematics

Move the sliders up and down for each field

BEFORE: Reflecting on STEAM (Criteria 3)

No more than 100 words per item

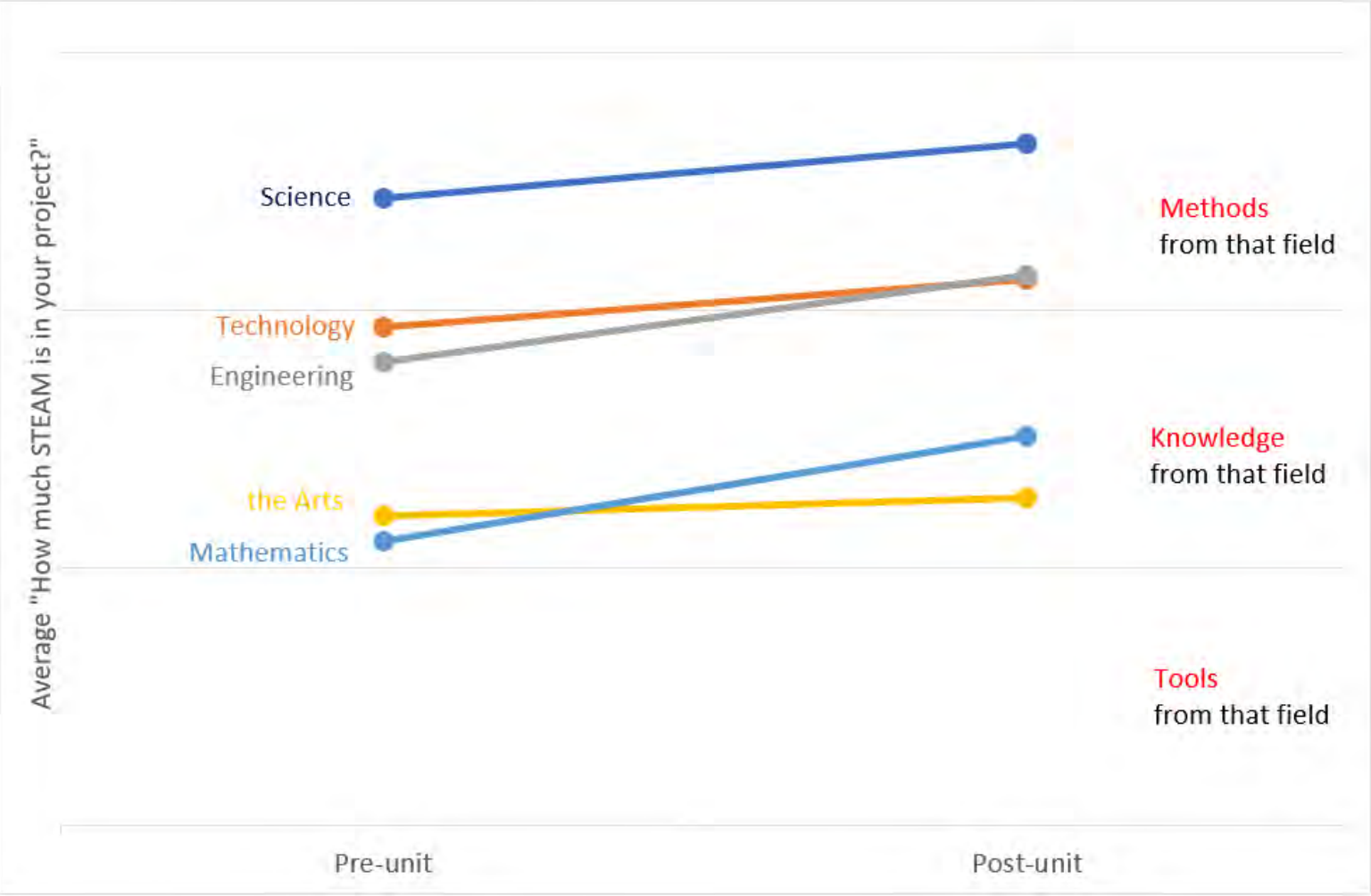
I would define STEAM as...	• An educational and life-long approach that addresses learning and development in the studies of Science, Technology, Engineering, the Arts and Mathematics.
I would define STEAM inquiry as...	• The use of Science, Technology, Engineering, the Arts and Mathematics in an inquisitive, self-directed educational technique that allows students to drive their own ideas, and learning through questions asked and theories learnt • STEAM inquiry allows the students to draw conclusions based on their own investigations
The STEAM inquiry model will be useful for my future teaching (1 - not at all useful, 10 - extremely useful)	• 2 - Unsure as to how I would implement this in my teaching thus far. However, this may change after completing this independent STEAM project.

AFTER: Reflecting on STEAM (Criteria 3)

No more than 100 words per item

I would define STEAM as...	• My definition stands that I still define STEAM as an educational and life-long approach that addresses learning and development in the studies of Science, Technology, Engineering, the Arts and Mathematics. • The Arts allows students to draw on mediums they may specifically be interested in, such as architecture, visual arts, music etc, as this is the centre of STEM. Without philosophies of Art, STEM
I would define STEAM inquiry as...	• STEAM encourages students to be curious and experimental • The use of Science, Technology, Engineering, the Arts and Mathematics in an inquisitive, self-directed educational technique that allows students to drive their ideas and learning through questions asked and theories learnt • STEAM inquiry allows the students to draw conclusions based on their own investigations
The STEAM inquiry model will be useful for my future teaching (1 - not at all useful, 10 - extremely useful)	• 8- after completing the inquiry-based assessment, I believe that the STEAM inquiry model will be beneficial and valuable for my future teaching career. • The model is individualised for each student and their Zone of Proximal Development. • The model stimulates curiosity, enhances student performance (the student is the centre of the learning) and I believe develops independent skills -all values which align with my teaching philosophy

How much STEAM is in your project?



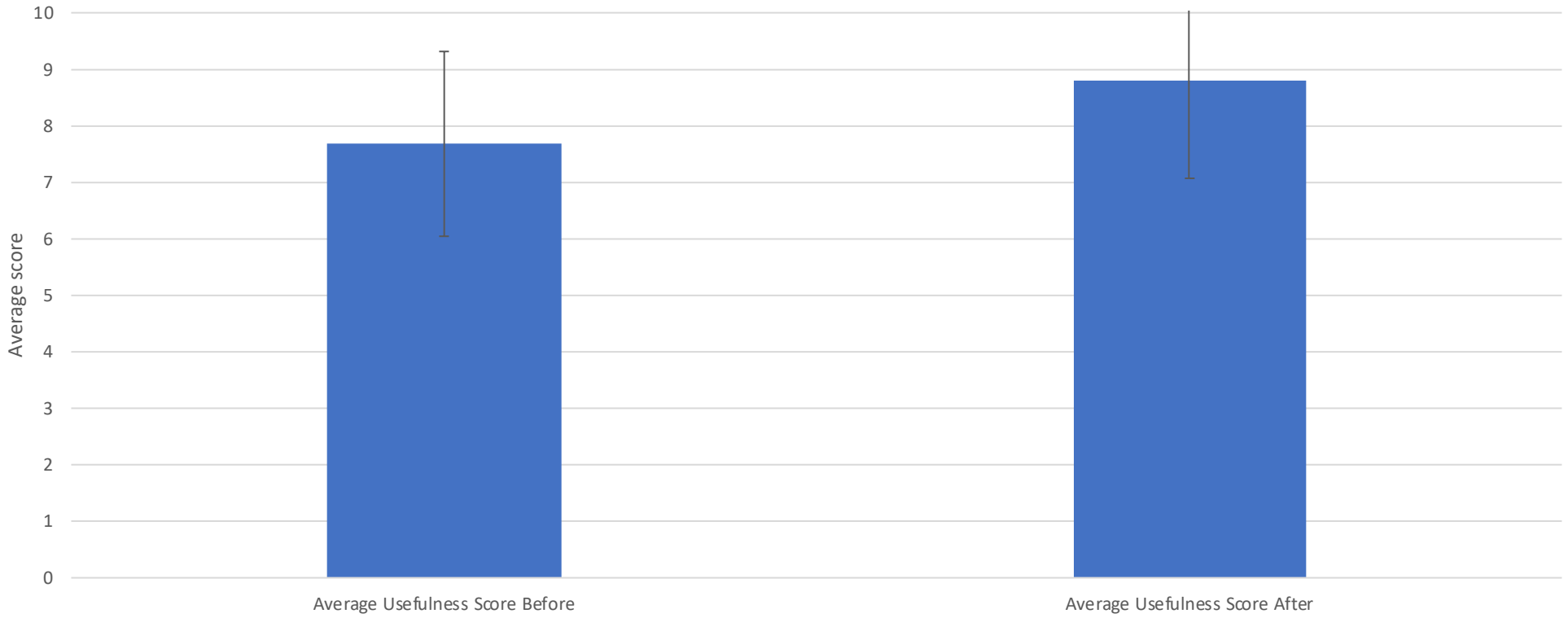
By the end of the inquiry, students were able to…

Identify that technology/engineering methods were used

Not identify mathematical inquiry methods were used

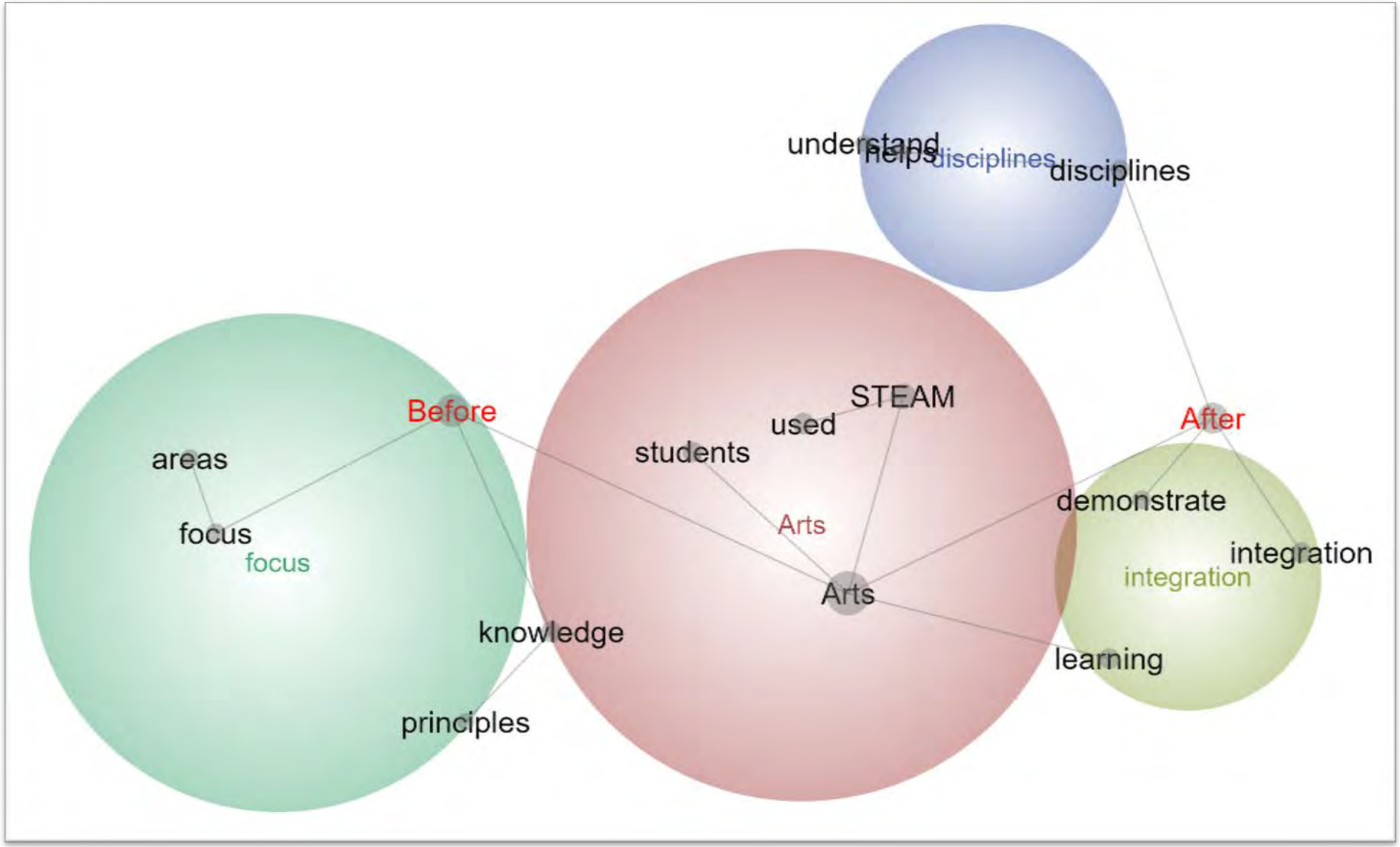
Identify only ‘knowledge’ from the Arts were used in this particular inquiry

How useful will the STEAM inquiry model to your future teaching?

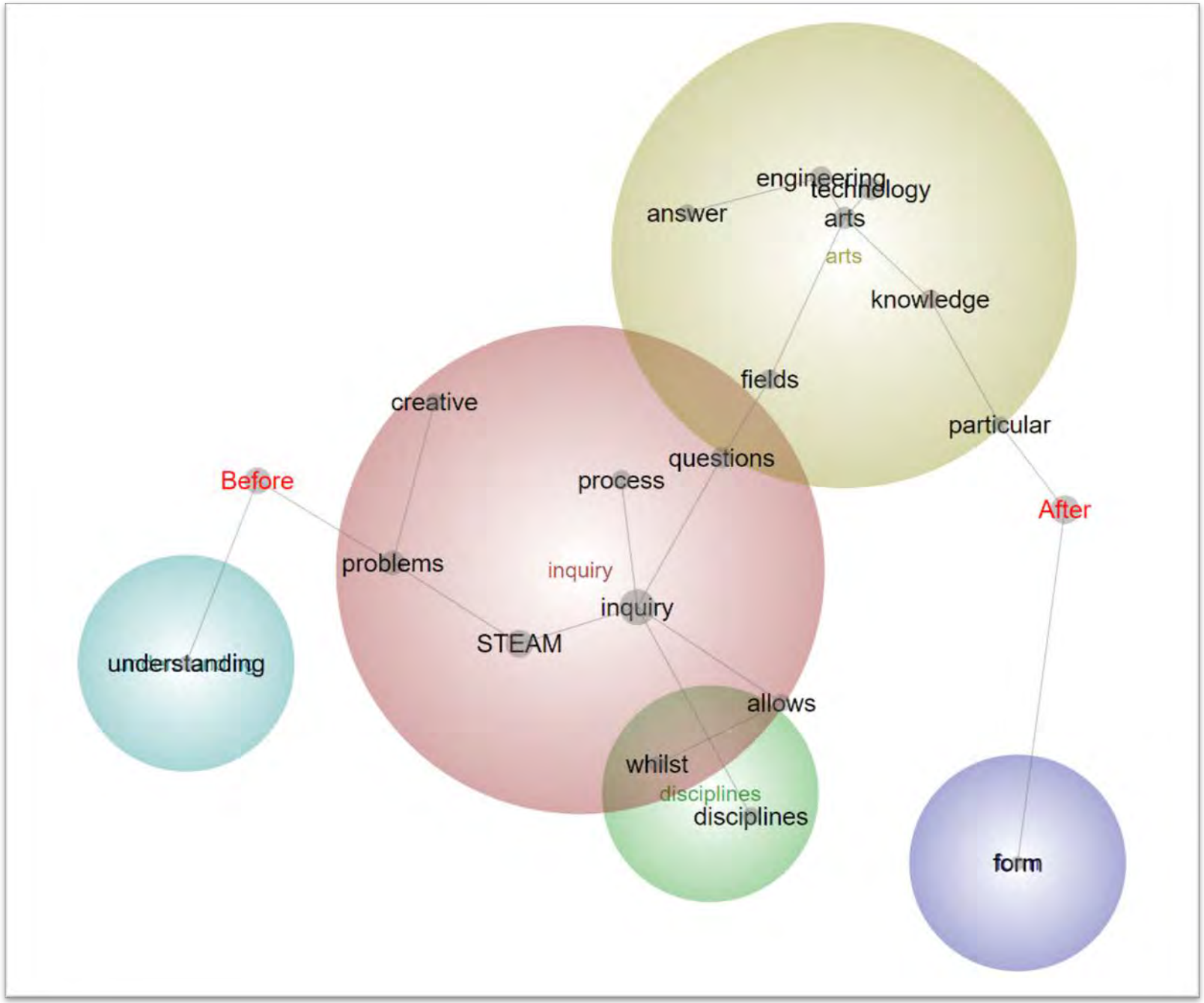


Participant ratings of the degree of STEAM in their projects changed over time as did their perceived usefulness of the model (t(13)=3.98, p=.002, d=0.39) to the teaching pre-unit (M=7.68, SD=1.64) and post-unit (M=8.79, SD=1.72)

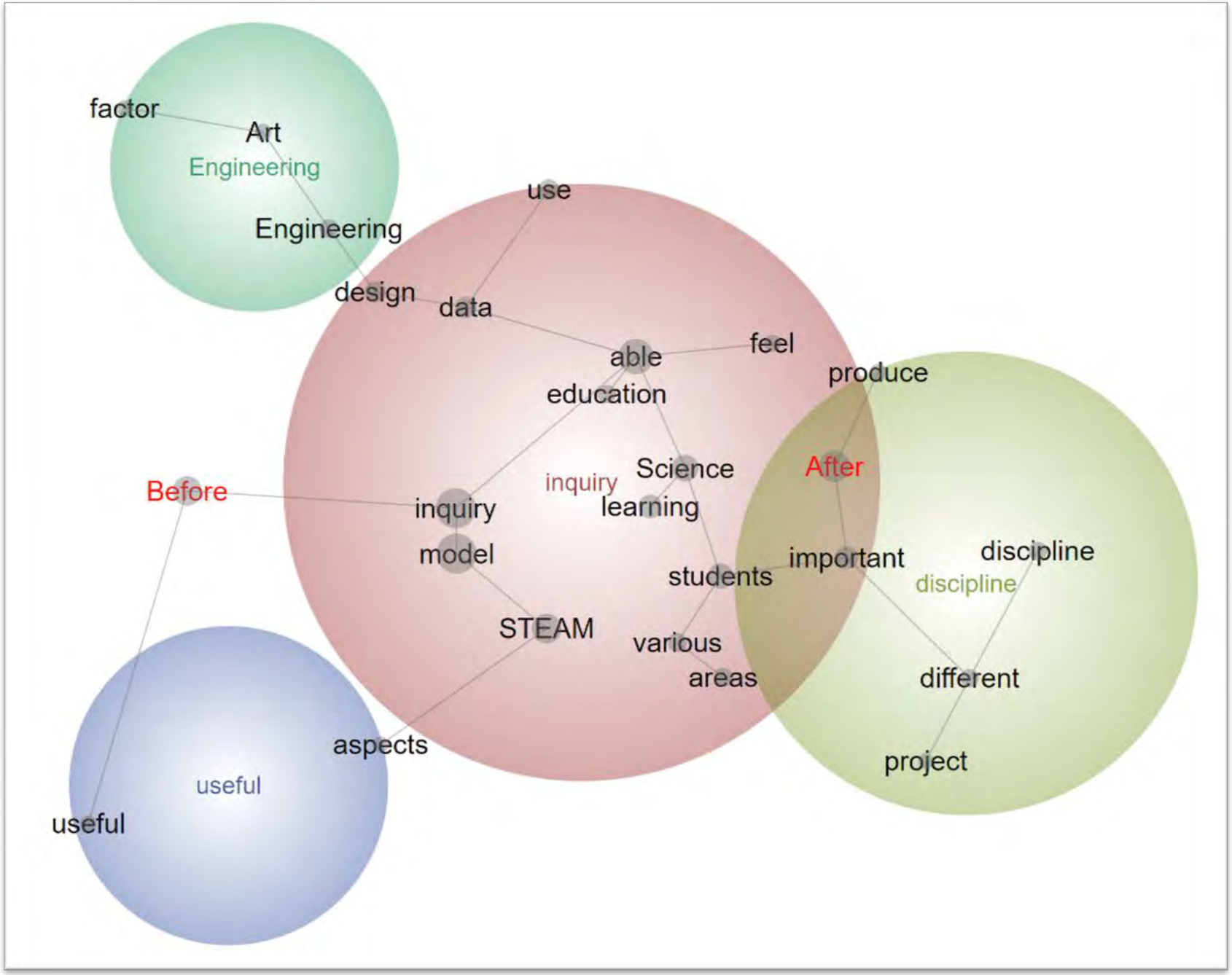
How did students define STEAM before and after?



How did students define STEAM INQUIRY before and after?



What did they say about the USEFULNESS before and after?



Where to from here?

- Allow free choice OR provide a menu
- Seed more mathematics and arts focussed inquiries
- Have STEAM and STEAM inquiry as a dedicated lecture topic

any questions or comments