Appendices

Astro-Animation: Gesture, Metaphor, and Creative Practice in Astronomy Communication

Laurence Arcadias

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Appendix A: Interview Instruments and Thematic Analyses

A.1 Semi-Structured Interview Questions for NASA Scientists

List of Questions to Scientists

This appendix presents the full set of semi-structured interview questions used in Strand 1: *Hand Gestures Interview to the NASA Scientists*, which formed the foundational data collection phase for the research. These questions were designed to elicit both spontaneous and

- Q9 Do you think your cultural background influences your gesturing? How might your gestures be interpreted by people from different cultures?

- Q10 Does the medium through which you are communicating (e.g., in person, video lecture, televised interview) affect how you use gestures?

- Q11 How has your use of gestures evolved throughout your career as you have gained more experience and knowledge in astrophysics?

- Q12 Are there any concepts that you find particularly challenging to illustrate with gestures? How do you handle these challenges?

- Q13 When doing tricks, stage magicians have a great way to use their hands, can you see some similarities with your own hand gestures?
  Does a hand gesture can be wrong or true? Sincere? misleading?

A.1.2: NASA Scientist Interview

(Dr Jeremy Schnittman— Astrophysicist, NASA Goddard Space Flight Center)

**The following transcript has been lightly edited for clarity, spelling, and readability while retaining the speaker's original tone and phrasing.

Date of Interview: 05/24/2024
Format: Recorded video interview (duration ~20 minutes)
Research Context: Conducted as part of Strand 1 of the Astro-Animation research project (*The Movements of the Universe*) exploring the relationship between scientists' gestures and their communication of astrophysical concepts.
Interviewer: Laurence Arcadias
Interviewee: Dr. Jeremy Schnittman, Astrophysicist, NASA Goddard Space Flight Center
Setting: Dr Schnittman 's Office / Zoom

Q1 What do you think of your hand gestures through this film?

I like it. It's funny, it's been a long time since we did this, but it's coming back quickly. The second one was particularly cool, the interaction with the trails from the fingers. I really felt like, especially in the second one, the live action was carefully and well integrated with the animation. I really like that, especially because the subject of black holes has always existed in two worlds: mathematics and observation.

It came from Einstein a hundred years ago, and for the first fifty years after Einstein, black holes were mostly in the world of theory and mathematics. Then they entered the real world of astronomy, through X-rays, radio waves, and telescopes. But there's still a lot of ongoing mathematical research, so the animation feels like it captures that connection—the way black holes and gravitational waves straddle these two worlds.

Q2 Do you think the animation + your hand gestures work together, if so, why?

Yeah, I think the hands worked really well.

Q3 What do you think are the main functions of your gestures when you explain astrophysics? Are they primarily for your audience's understanding, your own thought processes, or both?

One thing I've noticed—whenever you watch science shows, speakers often don't know what to do with their hands. If you're sitting, you can keep them still, but when you're standing, hands can be awkward or distracting unless they contribute to the story. For this project, the hand movement was a conscious contribution to the story, and that worked well. Often, if you don't do it consciously, hands can be a distraction because people don't want to just stand without moving their hands.

Q4 Do you practise your hand gestures, are they learned gestures or intuitive?

For the one we did together, it was more conscious, not entirely intuitive. Although we picked a good topic, processing tops, which naturally lends itself to gesture. If I were giving a talk at a conference, I'd probably be doing the same thing. For regular talks, I don't practise gestures; I try not to think about them too much, because when I do, I feel awkward. It's better to let them be natural, though that can be hard

Q5 Did you take public speaking classes? How has this influenced your gesturing?

We have done some. I don't know if it'd be called public speaking classes. They've done what we call at NASA here. Media training. So it's similar, you know, how to talk to the media, how to do interviews. But I don't think. I don't think hand gestures ever came up.

Q6 Do you gesture differently with different audiences, for example children versus adults?

The difference depends more on the venue than the audience. When I talk to children in classrooms, I'm much closer to them, so gestures have to be smaller or they can feel aggressive. On a big stage, you have to exaggerate, like an actor, so people far away can feel the energy

Q7 Have you ever received feedback (positive or negative) about your hand gestures from peers, mentors, or your audience?

I don't think so. Everyone has a similar instinct, t can feel awkward when you're standing and just talking. When sitting, gestures can be easier to use to describe something. Over the last few years working with students, I often use gestures on Zoom to explain concepts. When I'm done, I can just stop gesturing, which is convenient, like putting the tools away.

Q8 Do you think hand gestures help memorize information?

Probably. When you move, you connect ideas differently. My wife still remembers when I explained two black holes on our first date—one rotating, one binary. She said she could see my excitement through my hands. Gestures show enthusiasm; when the speaker is excited, the audience feels it too.

Q9 Can you recall any specific instances where a particular gesture helped convey a concept more effectively? What was the concept, and what was the gesture?

That same story with my wife, it helped her understand and, well, it helped her fall in love with me. You can't ask for more than that.

Q10 you think your cultural background influences your gesturing? How might your gestures be interpreted by people from different cultures?

There's a reputation for Italians speaking with their hands. In my family, we're more reserved, so for me, gesturing is more of an acquired skill—something I consciously think about.

Q11 How has your use of gestures evolved throughout your career as you have gained more experience and knowledge in astrophysics

I've probably been using the same gestures and stories for 20 years. Gestures help give a visual picture—I'm a very visual learner—and they convey enthusiasm. They make things tangible and inclusive, more honest somehow: 'nothing up my sleeves.' Equations can exclude people, but gestures include them. It's like sign language for science, a physical symbol of wanting to reach everyone.

Q12 When doing tricks, stage magicians have a great way

Hopefully, I'm doing the opposite of that! Magicians use gestures to distract, while I use them to make things clearer and more transparent.

Q13 so do you have anything I said you want to tell me about your HANDS?

This is more than I've thought about my hands in many years! It's made me very conscious of them, but hopefully in a good way.

End of transcript.

A.2: Thematic Interview Matrix:

NASA Scientists' Responses to Gesture Use in Animation and Communication

Theme	Interview Question	Dr. Schnittman	Dr. Mather	Dr. Ojha	Dr. Corbet	Dr. Caputo
Animation/Science Integration	How do your gestures interacted with my animation in the film?	"The real world interpreted with the animated world..."	"My message + the animation and the hand gestures work perfectly"	"The animation and my hand gestures blend seamlessly..."	"The message I was trying to convey worked well with the animation"	"I liked when I was talking about a galaxy and suddenly there was a galaxy swirling in."
Awareness with Hand Gestures	Are you aware of how you use your hands when explaining scientific concepts?	"When I think too much about them, it feels awkward…"	"I mostly speak with words..."	"My gestures are intuitive and untrained."	"In the classroom, I illustrate the Doppler effect by spinning around"	"I naturally talk with my hands a lot."
Gestures & Memorisation	Do gestures help people remember scientific ideas?	"When we link gestures to information, it sticks."	"Probably yes."	"I remember teachers using dramatic gestures..."	"When I do physical demonstrations, it helps people remember."	"It's hard for me to know… but I think it would aid…"
Emotional Functions of Gestures	Do gestures help express your excitement or connection to a concept?	"My wife remembers me explaining black holes..."	"Here it shows my excitement about the grandeur…"	"My enthusiasm makes the audience more engaged."	–	"When I am excited, I become more expressive."
Gesture & Medium	Do you change your gestures depending on the medium (e.g., Zoom, stage, classroom)?	"I have to over-dramatize on stage to make sure the audience follows."	"I do mostly outreach speaking, and I use words…"	"Larger gestures for big audiences, smaller for 1-on-1."	"I don't see myself changing gestures depending on the medium."	"It's a great way to connect to people."
Comparison to Magicians	How do scientists' gestures differ from performers like magicians?	"There's nothing up my sleeve! My hands are here to explain."	"Magicians use their hands to mislead us…"	"Scientists and performers both use gestures strategically."	"Magicians mislead, scientists clarify."	–

Appendix A.3

A.3: MIRO Table

Thematic Analysis of NASA Scientist Interviews on Hand Gestures

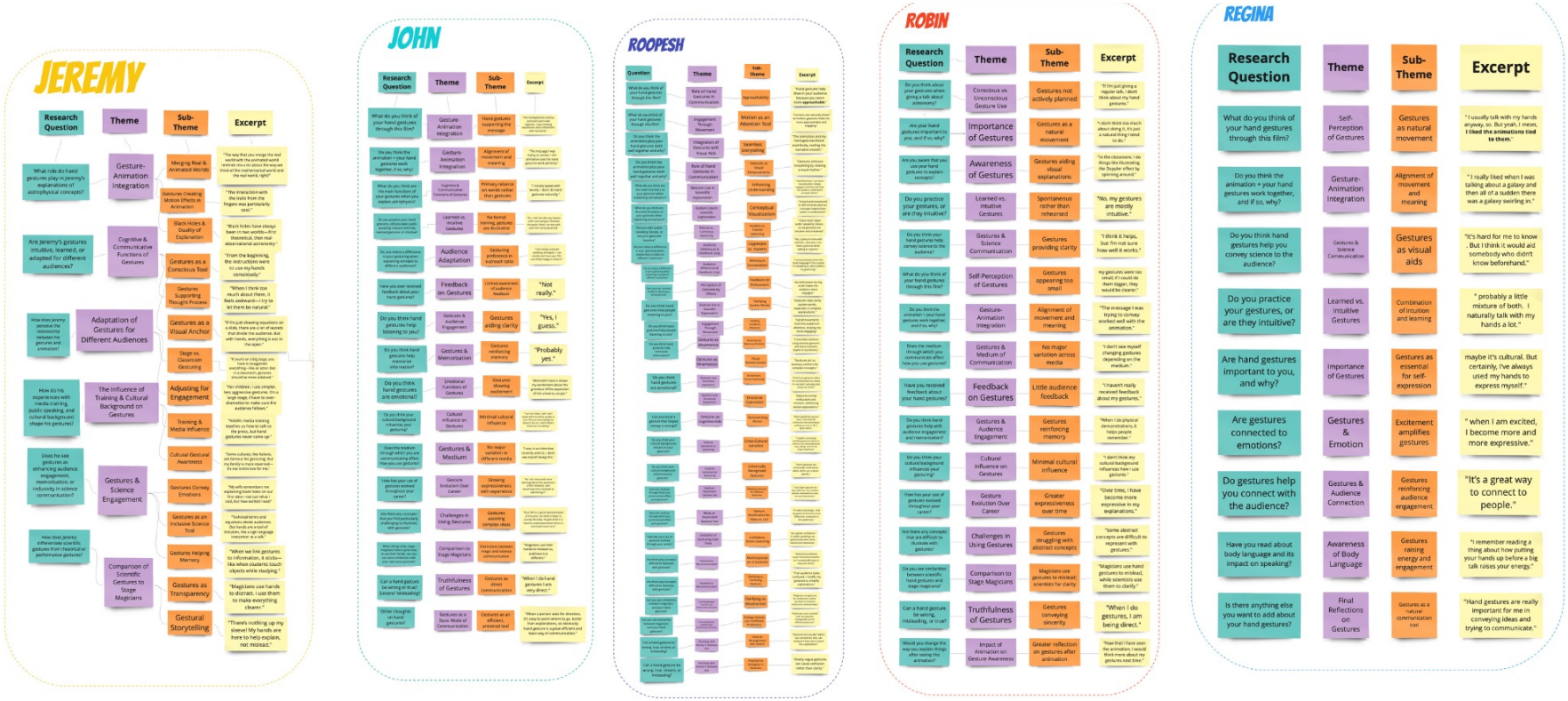


Figure A3: QR code linking to interactive MIRO board of gesture-themed interviews

https://miro.com/app/board/uXjVK6NhC2I=/?share_link_id=151920669269

A.4 Thematic Coding Matrix – Pratt Library Family Workshop

Pratt Library Family Interviews- Participant 1

Question 1

What are you drawing?

Answer 1

I'm just trying to make it, like, start out and balloon out and I've got him eating the flower.

You've got him eating the flower?

Yeah. I didn't really know how to make it pretty good but yeah. Well, I had it in my mind that it was going to start out small and then get bigger, but I didn't know totally how to do that so…I mean, I've never- I've never messed with animation before in my life, so yeah.

So do you know what you're drawing exactly?

Well this one I did just as an experiment to see (gestures to previous attempt), and then I thought, well I could do- I could do a sailboat. See, part of it is it's four frames per second, but in my mind I don't really know how long I should be, you know? I mean I should probably be doing all these frames the same, but in my mind I don't know how much a second is. It's kind of like having a kindergartner with paints for the first time cause I really don't know. So I could probably continue this and then have another something eating the boat or crashing into it or something. Idon't know what else to do.

Question 2

Awesome, so are there any new facts that you've learned today from the workshop?

Answer 2

Oh, I learned about Pluto. Cause I always wondered why all of a sudden it wasn't a planet. It just didn't make sense to me. And then he explained it was a dwarf and they didn't want to make all the dwarfs planets and then I understood. It's just a lot easier just to take- to demote the one planet then to have to do all of the dwarfs. Yeah, so that's what I learned today.

Question 3

So my last question is what did you enjoy the most out of this?

Answer 3

I don't know, it's just different. I don't know, it's just different. I like learning new things and…yeah. I should probably do something like a fish or something like that cause that would be easier to you know like I don't really have a theme in my story.

Pratt Library Family Interviews- Participant 2 (VENUS)

Question 1

What are you doing here and why?

So this is a spacecraft. I'm not sure if I wanted it to crash land or gracefully land yet, but it's getting the crashland vibe so far. But yeah, that's kind of where I'm at with it so far- I'm trying to figure out where else to go with it though.

Is there any particular reason why or is it something that came off the top of your head?

Um, yeah! I just kinda started drawing. So, I started with- I was making a fish, like *that* particular fish (points to presentation slide) and then I was like 'eh, I'll turn it into a spacecraft' and I think because of the angle its at right now, um, to me it's looks like it's shocked by the gravitational pull on whatever this planet is. So because of that angle I was like 'eh, crash landing. That might make sense.' So that would be the particular reason.

Question 2

Awesome, so did you learn anything? New facts from this workshop?

About animation or about astronomy? Or about both?

Anything!

Answer 2

Um, I did! I've always been interested in animation. I'm, like, working on a film- a documentary and I'm really interested in possibly incorporating animation into it, so I didn't know about the spacing things. So like the fact that if- like depending on- and it may seem obvious now, now that I'm looking at it, but I didn't realize spreading it out makes it go faster and making it closer kinda slows it down. I also didn't know that one second is twelve frames. I didn't realize- like I always knew animation was, like, *work* but I didn't realize the extent to which. One second being 12 framed is like, that's real work. So yeah, that's one thing I learned.

Question 3

Is there anything about this that you have enjoyed so far?

Answer 3

Um, I really just enjoyed exercising this creative muscle. It's been a cool process so far. I'm really enjoying just the challenge of starting it and then figuring out where I'm going with it. Just the process I've enjoyed a lot.

Follow Up- Question 4

Did animating help you understand astronomy better?

Answer 4

I would say that I think that it helped me to be able to *touch* it more, if that makes sense. Like, it's a little more tangible to me. It's not as in the stars anymore, it's not as in the sky. It's more sort of on paper. So I guess in that way, it definitely did help me to understand it better.

Follow Up- Question 5

Has the workshop changed how you see Art and Science?

Answer 5

Um, yes. I've always been a person that has been very passionate about the combination of the two. I'm currently in my masters in public health, but I try to use storytelling and visuals as a means through which I'm able to communicate health messages. I would say it has helped me to see it in another way. Cause again, the visual art that I tend to do is filmmaking and photography, so I'm not as familiar with animation. But I feel like in doing this I'm also in this world that I'm creating (gestures to drawings), cause I am the creator of this world. So I would say that it's helped me to understand it and have a little bit more of a connection with it.

Follow Up- Question 6

Are interested in working in Art or Science in the future?

Answer 6

Oh yeah absolutely. That's, like, what I really want to do. I feel like even going back to the Renaissance, a lot of the greatest artists were also doing science related things, so I feel like the two are very intimately connected and I think that to get to a point in which- to solve a lot of the problems that our world has- thinking about Art and Science as intimately connected… I think that's the future.

Pratt Library Family Interviews- Participant 3 (GAMMA RAYS)

Question 1

What are you doing here and why?

So what I'm drawing is like some stars and I was trying to get like, slowly a little explosion thing around it, so that way it could seem like it's being shot across the planet. And the arrow thing was…I don't know, the arrows just riding him (laughs). Arrow's just riding him. But, yeah, I'm basically planning on adding a couple more stars- probably like a couple more right here
(gestures to drawing)- so that way they can feel like they have a little golden glow to them.

Question 2
Are there any new facts that you've learned from the workshop?

Answer 2
Uh, actually, for real, most of the stuff I already knew, for real. Like, I knew that Pluto was once a planet- it became a dwarf planet. I already knew most of the stuff, I just couldn't remember the other dwarf planets and like the outer belt.

Question 3
What was it that you enjoyed most about this?

Answer 3
Most of what I enjoyed about it was relearning about Pluto again and like learning about the other dwarf planets, cause y'know Pluto got demoted (laughs). But yeah, this has been like a real fun experience though.

Follow Up- Question 4

Did animating help you understand astronomy any better?

Answer 4

Well, yeah? But also with the help of, like, The Magic School Bus, Bill Nye the Science Guy, Neil Degrass Tyson- all of that kinda cultivated how we realize space is actually pretty fun! But dangerous (laughs).

Follow Up- Question 5

Has the workshop changed how you see Art and Science?

Answer 5
Nah. I still feel like art is amazing and science is wonderful.

Follow Up- Question 6

Are you interested in working in Art and Science in the future?

Answer 6

Sure! I wouldn’t mind (laughs). I wouldn’t mind.

Pratt Library Family Interviews- Participant 4 (SATURN)

Question 1

What are you doing here and why?

I'm drawing a guy that looks like Baymax slash Michelin man just jumping around (laughs), just cause he's having fun! He's having a good ol' time! He learned that Pluto takes really long to rotate, y'know, so he's just having fun.

Question 2

Is there anything that you enjoyed most about this?

Answer 2

Honestly, all of it. I enjoyed getting to speak to a scientist from NASA and also just learning from a PhD candidate from MICA and like, yall are here helping out and it's been cool chatting with all of you. And it's my first time doing an animation like this, so that's been really nice.

Follow Up- Question 3

Did animation help you understand astronomy better?

Answer 3

Not so much in this case, but definitely just like I can see it, you know working that way. I was chatting about that with Robin and I think it definitely is beneficial to have art and science together to promote learning on whichever topic it is, but astronomy for sure. It's nice to have those images so, yeah.

Follow Up- Question 4

Are you interested in working in Art and Science in the future?

Answer 4

I am, yeah! Not so much in the astronomy realm, but I do- I currently, I'm going to school- about to finish up- with a public health degree. And so something I wanted to do was incorporate disease prevention with art for children and also it's just like not just animation and drawing, but also music- that kind of thing- to promote education for kids and just the general population.

Pratt Library Family Interviews- Participant 5 (MERCURY)

Question 1

What are you drawing and why?

Answer 1

I'm trying to do some drawing and use some stickers. So first I wanted to show some movement, so I created little squiggly lines to show Pluto vibrating and then I wanted to show things getting bigger as

the frames went on, so I started with little dots in the same color as the stickers and then I transitioned into small stickers and then larger stickers.

Question 2

And what new facts did you learn from the presentation or maybe this activity as well?

Answer 2

I learned the reason why Pluto was ejected from the term 'planet.' I never knew before why, I

just thought - I think the reason was like "if we call Pluto a planet then we have to call everyone a planet," which was interesting. And I didn't know one second of animation typically has twelve frames- that was interesting.

Question 3

What did you enjoy the most about this activity?

Answer 3

I enjoyed being able to try it out. I'm interested to see what the video at the end looks like and see if I can pick out my one second of video.

Follow Up- Question 4

So, what have you been doing so far?

Answer 4

So far I've created a star expansion animation that'll be very very short because it's only four frames, but I started with some metallic pen and then I put stickers.

Do you like it? Do you like the process?

Yeah, it's really fun! It's fun to think in advance about what it's going to look like after.

Follow Up- Question 5

Did you find some difficulties at one point in this workshop to do animation? Did you have some downsides in doing animation or joy?

Answer 5

It is really fun. I'm excited to see what it looks like, I think, because I've never done it before. I don't know how it's going to look, so I'm just trying things. That's the most difficult part- is I wish I could try something and see what it looks like and change it after, but I just have to try it and see what happens!

Follow Up- Question 6

Do you think doing animation helps you understand the science that we were talking about? Do you see the connection?

Answer 6

I see the connection between all of the photos as they were traveling past Pluto and actually being able to see the planet. It looked so much like a video even though it was just photos- one after the other- so that definitely helped me. And it helps me to understand how many frames it takes to animate something because when you handed out the photos, they all looked the same (laughs). Because it's just a fraction of a second, I guess.

Follow Up- Question 7

Would you consider doing a job in either science or art or both together?

Answer 7

I don't think so. Only because I work at the library (laughs), so you can't steal me away from that. But, as a child I actually- my dream job was to be a stop motion animator. So that's why I wanted to come to this! It's for my inner child.

And what about the astronomy side? Do you have any interest in astronomy?

I do. My parents are physicists, so I have been brought up to appreciate science.

Pratt Library Family Interviews- Participant 6

Question 1

So, what's happening here (gesturing to animation)?

Answer 1

When the alien popped up, they got scared.

They got scared by the alien? Is this the alien here?

But turns out the alien spaceship is also broken! But this one got mad and that one's just trying to get him to stop.

And did it work?

I’m trying to do that now.

Pratt Library Family Interviews- Participant 7 and 8

Question 1

What are you doing here? (gestures to animation)

Answer 1

Guy: So for our idea, we're basically starting out with a little planet and that's (gesturing to drawing) going to be the meteor which is going to eventually collide into it.

And then it's going to do like a starburst?

Girl: It's going to do like a solar blast or something similar to that and turn it into a star.

Question 2

What did you enjoy most in this workshop?

Answer 2

Girl: I think all of it! Because without each of the gears it would never become what it would be sooner or later at the end result and I think that that's the most important part, because without all those tiny details, how would you understand the full result?

Guy: Yeah, that's kind of for all animation, though. I feel like a lot of people don't really see the small details in a lot of stuff. Like, for example, if you watch anime or if you watch any cartoon, it's a lot of small details or if it comes to a small part in the hand or some sort of flowy animation or clothes- a lot of people don't realize, but it all adds up to eventually become that one animation that you know and love.

Girl: Exactly, that's why I said every small animation counts. And I know the struggle for the most part, but with how many frames it would take to get one smooth animation? (makes noise). Well, it depends what method you use, but still you need to make one smooth animation. *Pain!*

Question 3

Do you think animation can help you understand science?

Answer 2

Girl: Yes, because I think that it would work out well with most of the students and other learners, because there are different types of learners as well. Either visual, audio, and hands on learners or touch- I forget the actual proper term for it- but I think animation helps with that cause you're able to do at least the top two for the most part- visual and audio learn. And at times, some teachers even let the students do hands-on learning as the animation is going and I love that a lot cause I think it helps all of the students learn at the same pace.

(Addressing guy) Anything you want to add to that?

Guy: Yeah! I like to think that it's actually one of the most important things towards science because if you, let's say- there's a lot of different subjects of science, but a lot of science subjects are very hard to comprehend, so animation not only allows you to kind of understand that- like it's a very good way to explain these concepts, which are very hard to understand on paper, visually, which allows you to finally get a grasp on what this is or what this means.

Question 4

Later, would you like to have a job that involves science and art or either or?

Answer 4

Girl: Of course! I feel like I'd be very much in my element in that job and I feel like I would love it so much.

Guy: I feel like it'd be fun. It'd be a good opportunity, y'know. It'd be really enjoyable to teach people or help people or even just do it ourselves in order to help people understand these big components which a lot of people can't get ahold of.

Code	Label	Definition	Example Quote
CE	Creative Experimentation	Use of metaphor, narrative play, or imaginative transformation in the animation process	"I started with a fish but turned it into a spacecraft."
EL	Emotional Learning	Expressing feelings of joy, surprise, awe, or confusion in learning	"I like learning new things… it's just different."
CL	Conceptual Learning	Gaining understanding of astronomical concepts through the animation process	"I learned about Pluto. I always wondered why it wasn't a planet."
VA	Visual/Aesthetic Appreciation	Describing appreciation of visual or kinetic qualities of animation	"It helps me to understand how many frames it takes to animate something."
AI	Art–Science Integration	Recognition of interdisciplinary value between visual art and scientific ideas	"Before, I didn't think art had much to do with science, but now I see how they work together."
CA	Career Aspiration	Mentioning interest in future jobs in art, science, or both	"I'd love a job that mixes art and science!"
BA	Barriers/Ambivalence	Expressing challenges, confusion, or mixed views on animation or science	"I wish I could try something and see what it looks like and change it after."

A.5 Thematic Coding Matrix – Pratt Library Teen Interviews

Question 1

What are you drawing and why?

Answer 1
I'm drawing like a circle.

Why are you drawing a circle?

Because it was the only thing I could think about.

Question 2

Did you learn any new facts from the presentation at all?

Answer 2

No.

Question 3

What did you enjoy from the workshop?

Answer 3
I'm not sure.

Follow Up- Question 4

Did animating help you understand astronomy better?

Answer 4

Yes, because I can visually see it, understand it. VC

Follow Up- Question 5

Has this workshop changed how you see science or art?

Answer 5

Yes.

Like what?

It made me see how fun it is to learn about planets. RefSC

Follow Up- Question 6

Are you interested in working in art or science in the future?

Answer 6

I'm interested in working in art.

Pratt Library Teen Interviews- Participant 11

Question 1

What are you drawing and why?

Answer 1

I'm doing big hearts and small hearts with wavy lines from the smaller the heart it is, the bigger the line is, to the bigger the heart is, the smaller the line is. M Em S

Why are you doing that?

It's to symbolize my heart can go from really small to really big. Yeah, my heart goes from big to small sometimes and I can go from mean to nice, so it's to symbolize that.

Question 2

Did you learn any new facts?

Answer 2

I learned a couple of new facts about Pluto that I never knew about and it was kind of cool, but I also didn't really learn nothing because I know a lot of things about Pluto. P K rei

Question 3

What did you enjoy from the workshop?

Answer 3
I enjoyed the fact that we get to be creative and express who we are. CSE

Follow Up- Question 4
Did animating help you understand astronomy better?

Answer 4
Yes it did. *movements and stuff*. KU

Follow Up- Question 5
Has this workshop changed how you see science and art?

Answer 5
Yes. Because it showed me different ways of art and different scientific movements and stuff. IA

Follow Up- Question 6
Are you interested in working in art or science?

Answer 6
Um, yeah.

Which one?

Science. Biology.

Theme	Definition
Visual Comprehension (VC)	Understanding scientific content better through visual representation and animation.
Reference to Scientific Content (RefSC)	Mentions of specific science-related content or realization during the workshop.
Motivational Expression and Symbolism (M Em S)	Use of symbolic or emotional imagery in artistic expression.
Prior Knowledge (P K rei)	References to previously known scientific facts or reinforcement of existing knowledge.

Creative Self-Expression (CSE)	Enjoyment or appreciation of opportunities for personal or creative expression during the workshop.
Knowledge Uptake (KU)	Acknowledgement of gaining a clearer understanding or learning new scientific concepts.
Interdisciplinary Awareness (IA)	Recognition of the integration of science and art or the possibility of engaging with both disciplines.

A.6 Thematic Matrix – Montgomery County Teen Workshop

Teen Interview Transcript

Facilitator: what are you drawing and why?

Participant 4: I'm animating a storm.

Participant: Yes, and I've always actually been interested in animation.

Participant (laughing): Why are you laughing?

Participant: I agree with that! You see him? He's never touched animation in his life. It's OK. That's a great mentality—I like that.

Participant: I don't like shaming friends. You know, people who want to get into animation should encourage others to join in. I've been doing it for years, and I want him to join me. I think it would be beneficial for the animation community to gain people.

Participant: Animation is so fun, and all of us can agree that if you use animation for educational purposes—like learning about aerospace or space—it could really teach people our age or even younger to enjoy science. I find animation fun, so if I see it used for education, I'd be more engaged.

Facilitator: Great! So, what did you learn today from the workshop?

Participant 4: I learned about storm characteristics.

Participant: I learned that I want to do something in aerospace. Also, I learned why gravity behaves the way it does in space.

Participant: Wait, gravity is still a thing in space. It just changes depending on your distance from a mass.

Participant: He explained that gravity in space isn't the same everywhere—it depends on your position and what's pulling you. If you're close to Earth, the gravitational pull is still strong. Even a million miles away, Earth's gravity still affects you, just less.

Participant: Exactly. It's relative to how far away you are from the object with mass.

Facilitator: That's right—and the equation that describes gravity, even in space, is Newton's Law of Universal Gravitation: $F = G * (m_1 * m_2) / r^2$ This means gravity never disappears; it just gets weaker with distance.

Participant (jokingly): I've also learned that the continuum mechanical version of Phillips has caused multiple cosmetic issues... (group laughter)

Participant: When two black holes collide, the energy involved includes both kinetic and potential energy. Before they hit, it's all potential. When they collide, it becomes kinetic.

Facilitator: Do you think doing animation helps you learn science?

Participant 4: Yes, definitely.

Participant: It's not the animation itself that teaches me the science, but because animation is involved, I'm more engaged. Kids like to be creative, having a creative aspect in education and learning things like this, really helps! that makes them more open to learning.

Participant: I'd have a higher tendency to want to learn something when animation is involved.

Facilitator: Did this workshop change how you see art and science?

Participant 4: Yes, I've seen how they can connect.

Participant: Yes. It made me think of creativity as a learning tool. Some of my friends have a hard time paying attention in school. This kind of learning could really help them.

Participant: I never thought people used animations to simulate planets and movements. It changed how I see NASA and science.

Facilitator: Are you interested in art or science in the future?

Participant 4: I'm not sure what counts as "art" here, but I love creative writing. Maybe something with NASA and storytelling.

Participant: Definitely. I'm passionate about science now, especially after learning about gravitational constants.

Participant: 100%. I want to go into something like mechanical engineering or computer science. I took AP Physics and got a 5 on the exam. I'd be very excited to pursue that because it's something I excel at, I was above my peers because I really loved the subject like phusics,

my friend loves the subject too and I think I would pursue l like passion, and once I am older, I would like to help the younger generation one day—because I didn't know where to go for resources when I was young.

Facilitator: Thank you.

Theme	**Color**
Scientific Understanding	
Creative Engagement	
Educational Impact	
Career Aspirations	
Art–Science Integration	
Facilitator Prompts	

A.7 Coded Participant Quotes from the HEAD 21 Conference

(HEAD 21 Conference, April 7–12, 2024)

This appendix presents the colour-coded thematic analysis of interview excerpts from the Eclipse Animation Workshop held during the HEAD 21 Conference (April 7–12, 2024). Each participant quote is aligned with the thematic categories established in Chapter 3 and coded according to the Eclipse colour scheme (Red: Myth and Cosmic Storytelling; Orange: Scientific Curiosity and Speculation; Yellow: Emotional Expression and Reconnection; Green: Material Exploration and Artistic Technique; Blue: Transformation and Movement; Purple: Collaboration and Shared Interpretation).

Theme	Colour Code	Participant Quote
Myth & Cosmic Storytelling		"It's like two stories. One is dog eating the sun… ten brothers being shot." (P1)
Myth & Cosmic Storytelling		"The bow… shoot the sun…" (P1)
Myth & Cosmic Storytelling		"The dialogue brings the sun back… from behind the dogs." (Kala)
Scientific Curiosity & Speculation		"I have the totality of the eclipse within one second… pi gets more accurate." (Thomas)
Scientific Curiosity & Speculation		"Earth is moving in weird orbits… a three-body interaction." (P10)
Emotional Expression & Reconnection		"I'm getting somewhere!" (P7)
Material Exploration & Artistic Technique		"I'm trying to make the eye look down… where should it go?" (Linda)
Transformation & Movement		"The owl waking up… taking off." (Nicole)

Collaboration & Shared Interpretation		"Is this a collaboration piece?" (James)

A.8 Coded Participant Quotes from LJMU/TransArt

(July 2024 in Liverpool)

Thematic analysis of interviews revealed a rich interplay of creativity, emotion, and learning, organised into nine interwoven themes that align with the visual summary in Figure 20.

[RED – Creative Inquiry] "I have no idea" (P6).

[RED – Creative Inquiry] "We can play with it" (P19).

[ORANGE – Courage & Vulnerability] Initial discomfort gradually gave way to expressive empowerment (P6).

[YELLOW – Emotional Resonance] "Pluto has the heart on the side… so much love" (P18).

[GREEN – Inner–Outer Connection] "Space… it's beyond comprehension" (P18).

[GREEN – Embodied Learning] Animation provided a more visceral, embodied sense of astronomical scale (P10).

[BLUE – Curiosity & Discovery] "Pluto was smaller than the US" (P17).

[BLUE – Scale & Perspective] "I was thinking of it as a spinning look" (P6).

[PURPLE – Interdisciplinary Synthesis] "Science and art both start with emotions" (P19).

[PINK – Memory & Identity] Reflective memories of early drawing linked to renewed creative belonging (P18).

A.9: Thematic Codes - Padova Transcript

Padova Interviews

Theme	Code	Illustrative Quote
Interdisciplinary Awareness	ART+SCI	Animation can be in every aspect of our lives. Yes, even in science.
Emotional & Aesthetic Engagement	AESTHETICS	The colours and movement made it feel alive. It was different than just learning facts.
Curiosity & Scientific Interest	CURIOSITY	I learned something about solar spots. And magnetic field... now I want to search for more.
Creative Freedom	CREATIVITY	I just want to go with the flow... I like creation and then destruction.
Cultural & Mythological References	CULTURE	I'm showing a mythological story... It's not scientific, but I think that's okay.
Reflective Learning through Animation	REFLECTION	While I draw... it helps me to think, to process the information.
Stress Relief & Emotional Well-being	WELLBEING	This makes me feel better and make me feel happy... we are stressed with the studies.
Skepticism or Modesty in Scientific Confidence	LIMITED_SCI	I know something about spots and magnetic field, but I'm not an expert.

Participant 1:

So what are you doing?

I have a little character on this place. Yes, he is going around. You see a little bird? Cute to create. Yes, yes, yes. Oh, he's going to catch this.. So when he's following the bird, The cat transforms. Yes. And he gets wings.

So, what did you learn today On the science level. Did you learn something from this presentation?

I've learned how animation is, so Animation can be in every aspect of our lives. Yes, even in science. Because without animation, we could not study or see the invisible.

Do you think mixing art and science together is helpful?

It's very helpful and Useful for children, For adults. For everyone.

Thank you very much.

Participant 2.

So what are you doing? Can you tell me?

I'm drawing fluid things and people. Yeah. And I know it is just an eye.

About knowledge And flowing people., that tall guy becoming, like, a spaghetti or something. It's like a fishbone, actually. That moves like something fluid too.

Do you like it?

Yeah, I love it. I'm delighted. I like the old story because, you know, you have to see it as a following thing. Because it's not just one drawing. It's like several drawing together. So I'm very excited to see how it's going to to be an animation.

So what did you learn today?. Did you learn something?

I learned something about solar spots. And magnetic field. I know something about spots and magnetic field, but I'm not an expert. So every time I listen to it and I think about it. Drawing, for example. Yes. I think I learn something new. Okay. Or I just want to search for more information So I will learn something.

And do you think doing the animation helps you to understand even better?

Yes. And usually when I study or when I design something, I think drawing too. And while I draw, even if I don't know what I am doing. It helps me to to think, to process the information. For example, the fluid things, they look fluid. And then it goes little bubbles here. Little fish. It's like going from the sun to the. It is beautiful. It looks like just light. But it moves with a strange turbulence. And so this was the idea..

And do you think do you think mixing up the science and and the art together is help you?

I mean, it's a good thing. Yes. I think it's really a powerful mix. Because we learn also by doing. It is very important. And the creativity can boost this. This learning.

Participant 3:

So what are you doing?

I don't know, I just want to go with the flow. Because I like flowers. Yes, I like butterflies. Yes. So I think I want to do something like creation and then destruction. Everything. Okay. That's great. That's beautiful. Thank you.

And did you learn something from Robyn's presentation today on the science level?

I didn't know anything. Yes, but I really liked the part on the sun and the fun facts on the sun.

And doing animation, does it help you understand the science better,?

Yeah. Yes I think yes, yes.

.

And do you think it's good to mix up science and art together for education ?

Yes. I don't think that every science, every kind of art has to be close in itself. I think communication between art and science is fundamental for increasing our knowledge in every field.

Participant 4:

So what are you doing? It's beautiful.

I wanted to tell the story of an astronomer. And maybe he or she went to this place, And he has a star and a moon. And he landed here and find that everywhere in he goes. With the stars it will grow with flowers and grasses. But if he go back and use the moon, it will disappear.

That's an old story.

So what did you learn from Robyn's presentation on the science level today?

I think before. Before this, this presentation, I learned animation just about Disney.

This car like. Yes. This animation films. But now I also got that it was very useful for the science and And for some theory areas.

And just doing the animation helps you understand the science better ? Y

eah, I think so. Yes. Sometimes, like, we cannot see some invisible things.

Because we don't have the macro micro machines. But using the animation. Yes. We can see perhaps what they are like.

And do you think the mixing animation and science together or art and science together does it? Is it a good thing? Does it help you think?

Yeah, I Think it makes the science much more interesting.

Participant 5

Can you tell me what you are drawing? It looks great.

I'm going to show a Mythological story in in China. It's beginning. There's no sun in the sky and it's too hot. People can't live in on the earth. And there's a there's a hero. His name is Hui anyway. And he. For saving these people. He shoot the suns, shoot other aid and saving the world. It's just a story. Very simple. It's not scientific, but I think That's okay.

Yes, of course, of course. Yeah. I remember when we are doing the eclipse, there was also a Chinese astronomer, and he told us a story about a dog who was eating planets. Does it seem familiar to you?

Oh, yes. I think that's a story of a Japanese or Chinese. I'm not very, I'm not sure. But yes, we've heard of that. That's like this story. It's not scientific, but it helps. Our parents will told us this story when we were children. We were scared about that. So what should we do? Can we live right? No.

what did you learn today? Did you learn something today with the science on the science level?

Yes. I learned a lot about this during this two days. Yes, I'm happy I could join this meeting.

And just doing animation helps you understand the science better?.

Yes,it Try and make me know better about animation. I like this because I learned cinema, but I didn't join a club like animation or produce this. It's a bit hard for me because I'm not good at painting. It's simple. It's really nice to see. Yeah, and those markers are great.

And sometimes we don't have a way to play, something like this. Yes. It's calm, it's easy. Make me feel at peace.. Thank you.

And you think art and science together is a good is helping?

It's helping me. Like me and other teenagers. Yes. Other students Fill our life. Because we are stressed with h the studies. Any articles and exam. It's tiring and this make me feel better and make me feel happy. And I'm more curious about astronomy and science and like your work. Yes. Yeah, it's very great. It's fantasy.

Thank you very much.

Participant 6

What are you doing?

Hi. I'm not good at drawing, so I just want to show the facial expression. In the process that human beings are explored. The movement. Yeah. Secret of the space. So I put the stars. So we made six presents together to show that how the human beings figure out that every planets, like stars and suns has held their own tracks to movements that to for the started human beings is very calm, peaceful. And since they are surprised to find out that the they are very new knowledge. Science world.

Just to figure out how to show it. So we are using those little expression.

So what did you learn on the science level through Robinson's presentation today.

it's totally new. And it's fine. So where's the sun's power?

And I learned how that animation and the animation of the science knowledge helps the children to learn. It's very fun.

And doing the animation. Does it help you understand the science better?

Yes. I know it's a process, because if I just use my imagination in my mind, first of all, I didn't have a enough knowledge to figure out. It's a lot of limitations for imagining. So now I can watch the animation. Yes, I can see clearly the process. It's very, very helpful.

Participant 7:

So can you explain me what you are doing?

We saw how to design a Sun. Yes. And that changes each frame.

And then a small flower that grows from this, from the ground and it burns. It is Water.

Burns and then dies and dies.

You are working on a same project?

Yeah, we are trying to. And then we are trying to figure out how.

And what did you learn today? Yeah, we can answer all together.

From the science part. What did you learn?

Well, some Information about the sun. In this specific way. How big it is Compared to Earth in particular. Yeah, yeah. And Its temperature. Some some fun facts.

It's so interesting. Interesting. Because. It's not something You take for granted.

And acknowledging some some specific. It's so interesting because I didn't know anything about sun. I thought I had some knowledge, but it's Just in general.

And doing animation can help you understand better.

Yeah in a a way. Yeah. I believe that it might help a lot in particular children as we we we said during the conference.

And and I really enjoyed the, the way of how it was explained. And I really liked your presentation and the previous days. And I like the way you spoke and was really communicative and I believe that it really worked.

Thank you very much.

Even from people that don't really know. Don't really know about science. And. Yeah, it was interesting. It it helped us To understand Better.

Learn something new. Okay.

Participant 8:

So what about you, what are you drawing?

I'm trying to following the black spots of the sun, okay, and trying to give them color, so bringing them alive and changing them. So i expect to transform them as the explosion goes on, so the color will sprout and with more not real drawing, but more realistic, yeah, I'm not sure.

Have an ideal if we could be done before five a week away. But you know, just give

me another day,

Where did you learn today? What did you learn?

I learned a lot about like the sun, because I studied when I was very little, so I didn't remember much about it. But I'm so fascinated about the universe and all of that. So like doing animation on something that it's real and alive, yes, kind of beautiful. So to me, it's very special.

And just doing animation helps you to understand better.

Can you explain it or more?

while drawing on it. A photograph is something that we cannot see with our eyes, but somehow it feels more with a more connected to it. So through animation that it gives movement to something that has not limbs, something that comes to our planet as well, even it's from so far away..

Participant 9:

So can you tell me what you are drawing and why

I'm trying to draw a little person here moving around. So I'm trying to do this because I have all the same image pretty much (from the film print)

yes, I'm just really draw better drawings.

and what did you learn today?

I always be really passionate about, like, astronomic stuff. So for example, seeing like people from NASA talking about sun is really exciting for me. So get to learn, a little bit about sun, because he explained a little bit, yes, some functional sun. And I am really excited to be like, to see what's the result.

.**And does doing the animation helps you to understand a little bit?**

I think so. Yes, I never, saw this kind of huge. So

it's gonna be cool at the end..

can you see the connection between doing animation and science together?

Yes, especially, okay,. And I think, like, when someone makes science and cinema is perfect, for example, my favorite movies *interstellar* so, like, that's the

So yes, I really love movie with movie, also animation stuff with science, stuff with science.

Participant 10:

What are you drawing?

It's really bad. It's really bad and unrealistic. thinking of like a heart that explodes. he likes and give his heart to everyone. Yes, the power of love.

Did you What did you learn today for this workshop?

I learned a lot. I learned first of all, space work, it was really interesting.

I didn't understand much since it's not one of my most common since I studied, like, films and movies, but it gives me a lot of idea for like, future projects

I'm really interested in, like being me. I was sort of like

aliens on to brought the two work together. and just doing the animation helps you to understand better, because it's really complex, especially since I stopped studying science when I was, in middle school, so a lot of years ago. So when there's animation or as we saw before, in little movies with the character, it makes it easier, because it's more fun. So you're getting better understanding.

Theme	**Participant insight**	**Interpretive summary**
Animation as a Tool for Visualising Science	"Without animation, we could not study or see the invisible."	Animation was understood as a way to make invisible or abstract scientific phenomena perceptible.
Learning Through Drawing and Process	"While I draw… it helps me to think, to process the information."	Drawing supported reflection and helped participants work through scientific ideas during the act of making.
Interdisciplinary Learning	"I think it's really a powerful mix. Because we learn also by doing."	Participants experienced the combination of art and science as an active, experiential learning process.
Creative Freedom and Personal Expression	"I just want to go with the flow… I like creation and then destruction."	Students used the workshop to explore personal imagery, transformation, and imaginative interpretation.
Cultural and Mythological Interpretation	"I'm going to show a mythological story… It's not scientific, but I think that's okay."	Cultural stories and mythological references became entry points for interpreting astronomical material.
Emotional Well-being and Engagement	"It's calm, it's easy. Make me feel at peace."	The activity supported emotional ease, enjoyment, and engagement

Theme	Participant insight	Interpretive summary
		within a demanding academic context.
Changing Perceptions of Animation and Science	"Before this presentation, I learned animation just about Disney… but now I also got that it was very useful for the science."	The workshop expanded participants' understanding of animation as a tool for science communication.

A.10 Comprehensive Participant Quote Table (Full Dataset)

This appendix collates verbatim quotations from participants across all Astro-animation workshops described in Chapters 4 and 5. Data come from post-workshop surveys (HEAD 21, Pratt-teens), semi-structured interviews with teenagers and adults (BSA, Pratt Library , Liverpool/Transart, Padova), and a small number of informal group interviews (Montgomery Teen Workshop). Responses were coded using reflexive thematic analysis to identify recurring motifs such as embodied learning, emotional resonance, curiosity, and interdisciplinary synthesis. Each entry lists a pseudonym or participant number, workshop context, research strand (2 = expert/public engagement; 3 = youth/community engagement), and a brief thematic label. The table is intended both as an evidential resource for the findings in Chapters 4–6 and as a record of participants' voices within the broader practice-based enquiry

1. HEAD 21 Expert Workshop- (Conference Scientists – Texas, Eclipse, Interviews)

Participant ID	Workshop	Strand	Quote	Theme
ECL-P2	Eclipse workshop	2	"It's a love affair between the Sun and this being that arrives… it creates life."	Narrative meaning-making / cosmology
ECL-P2	Eclipse workshop	2	"The spaceship turns into an eye… it absorbs the identity of the Sun."	Metaphor / transformation
ECL-P8	Eclipse workshop	2	"When the eclipse starts, the cloud covers it and then clears away… the trees die, the owls go crazy…"	Environmental storytelling / cause–effect
ECL-P14	Eclipse workshop	2	"I'm learning how to blend the markers… I did! Learning about art, how to make it do what I want it to do."	Process learning / tool experimentation
ECL-P14	Eclipse workshop	2	"I have not done art in long enough… I'm so glad you brought this!"	Returning to art / wellbeing
ECL-P15	Eclipse workshop	2	"It's a collaboration piece… he's taking this last frame and rolling with it."	Collaboration / shared authorship
ECL-P7	Eclipse workshop	2	"You know, I'm getting somewhere."	Incremental progress / confidence

2. HEAD 21 Expert Workshop (Conference Scientists – Texas, Eclipse, Post-Surveys)

Participant ID	Workshop	Strand	Quote	Theme
H21-P1	HEAD 21 survey	2	"It was very great!! I enjoyed it very much :)"	Enjoyment / affect
H21-P2	HEAD 21 survey	2	"Thank you for bringing more explicitly creative elements into astronomy."	Creativity in science communication
H21-P3	HEAD 21 survey	2	"I think it worked really well!"	Perceived effectiveness
H21-P4	HEAD 21 survey	2	"Would love to collaborate on other astronomy–art projects in the future."	Future collaboration / interdisciplinarity

3. Liverpool / Transart Expert Workshops (Artists- Post-Surveys)

Participant ID	Workshop	Strand	Quote	Theme
LVP-P14	Liverpool/Transart	2	"It gave me a visceral, embodied sense of the scale."	Embodied learning / scale
LVP-P6	Liverpool/Transart	2	"I was thinking of it as a spinning look."	Temporal–spatial imagination
LVP-P18	Liverpool/Transart	2	"Pluto has the heart on the side… so much love."	Emotional resonance / symbolism
LVP-P18	Liverpool/Transart	2	"Space… it's beyond comprehension."	Awe / existential reflection
LVP-P19	Liverpool/Transart	2	"Science and art both start with emotions."	Interdisciplinary synthesis / emotion
LVP-P12	Liverpool/Transart	2	"At first it felt uncomfortable, but then it became fun."	Vulnerability → confidence
LVP-P6 & P19	Liverpool/Transart	2	"I have no idea… We can play with it."	Creative experimentation / play

4. Pratt Library / "Flying by Pluto" (Families & Adults – Interviews)

Participant ID	Workshop	Strand	Quote	Theme
PL-P1	Pratt / Flying by Pluto	3	"I've never messed with animation before in my life… it's kind of like having a kindergartner with paints for the first time."	Beginner mindset / experimentation
PL-P1	Pratt / Flying by Pluto	3	"I learned about Pluto… why it wasn't a planet… then I understood."	Conceptual clarification (Pluto/dwarf planets)
PL-P2	Pratt / Flying by Pluto	3	"I didn't realize spreading frames out makes it go faster and making it closer slows it down… one second being 12 frames is real work."	Principles of animation / craft awareness
PL-P2	Pratt / Flying by Pluto	3	"Animating helped me touch it more… it's not as in the stars anymore. It's more on paper."	Tangibility / grounding astronomy
PL-P2	Pratt / Flying by Pluto	3	"I feel like in doing this I'm also in this world that I'm creating… it's helped me to have more of a connection with it."	Immersion / world-building
PL-P3	Pratt / Flying by Pluto	3	"Most of the stuff I already knew… but this has been like a real fun experience."	Relearning / enjoyment
PL-P3	Pratt / Flying by Pluto	3	"Magic School Bus, Bill Nye, Neil deGrasse Tyson… all of that cultivated how we realize space is actually pretty fun! But dangerous."	Prior media / science imaginaries
PL-P4	Pratt / Flying by Pluto	3	"I enjoyed getting to speak to a scientist from NASA and a PhD candidate from MICA… my first time doing animation like this."	Role models / new practice
PL-P4	Pratt / Flying by Pluto	3	"I can see it working that way… it's beneficial to have art and science together to promote learning."	Perceived educational potential
PL-P5	Pratt / Flying by Pluto	3	"I didn't know one second of animation has twelve frames… I'm excited to see what it looks like, I've never done it before, so I'm just trying things."	Process excitement / uncertainty

PL-P5	Pratt / Flying by Pluto	3	"It looked so much like a video even though it was just photos… that definitely helped me."	Sequential imagery / motion perception
PL-P7 & P8 (pair)	Pratt / Flying by Pluto	3	"Without all the tiny details, how would you understand the full result?"	Detail / accumulation
PL-P7 & P8	Pratt / Flying by Pluto	3	"Animation helps visual and audio learners… sometimes even hands-on. It helps all students learn at the same pace."	Learning styles / inclusivity
PL-P7 & P8	Pratt / Flying by Pluto	3	"It's one of the most important things towards science… concepts that are hard on paper become understandable visually."	Visualisation of complex concepts

4B. Pratt Library Teen Workshop (interview)

ID	Workshop	Strand	Quote	Theme
PT-P10	Pratt Teen/ Flying by Pluto	3	"I'm drawing a circle… it was the only thing I could think of."	Drawing choice
PT-P10	Pratt Teen/ Flying by Pluto	3	"No." (learned new facts?)	Limited factual learning
PT-P10	Pratt Teen/ Flying by Pluto	3	"I'm not sure."	Neutral engagement
PT-P10	Pratt Teen/ Flying by Pluto	3	"Yes, because I can visually see it, understand it."	Animation aids understanding
PT-P10	Pratt Teen/ Flying by Pluto	3	"It made me see how fun it is to learn about planets."	Positive shift in science attitude
PT-P10	Pratt Teen/ Flying by Pluto	3	"I'm interested in working in art."	Career interest
ID	**Workshop**	**Strand**	**Quote**	**Theme**

PT-P11	Pratt Teen/ Flying by Pluto	3	"Hearts… to symbolize my heart going from small to big."	Symbolic expression
PT-P11	Pratt Teen/ Flying by Pluto	3	"I learned a couple new facts… but also didn't really learn nothing."	Mixed factual learning
PT-P11	Pratt Teen/ Flying by Pluto	3	"We get to be creative and express who we are."	Creative engagement
PT-P11	Pratt Teen/ Flying by Pluto	3	"It showed me how everything works and moves."	Animation aids understanding
PT-P11	Pratt Teen/ Flying by Pluto	3	"Different ways of art and scientific movements."	Shift in art–science perception
PT-P11	Pratt Teen/ Flying by Pluto	3	"Science. Biology."	Career interest

5. BSA High School Workshop (interviews)

Participant ID	Workshop	Strand	Quote	Theme
BSA-P1	BSA	3	"Photography and animation can be used to capture stars and the sun and help us understand the universe better. Very cool."	Visualising astronomy / enthusiasm
BSA-P2	BSA	3	"I learned a lot of new ways of doing animation… about Galileo and his influence on animation."	Technique + history
BSA-P3	BSA	3	"It's fun to have a class that provides both space and art… I've always liked animation and science and they are connected in my mind."	Integrated interests / validation
BSA-P4	BSA	3	"I did not know that science and animation were so connected. I like that."	New art–science awareness
BSA-P5	BSA	3	"Seeing a visual source to show the information… helps understand different scientific terms and seeing the sun orbits around."	Visual explanation / terminology
BSA-P6	BSA	3	"Galileo took pictures of the Sun – very cool."	Historical insight

BSA-P7	BSA	3	"I did not know they [art and science] were so close, like intertwined, and I like that."	Intertwining disciplines
BSA-P8	BSA	3	"It's something unexpected, I did not think [art and science] could connect. That's pretty interesting."	Surprise / reframing
BSA-P9	BSA	3	"I understood that art can help science… people can understand better; they get more knowledge from stuff they don't understand with words. But visually, they can."	Accessibility / visual literacy
BSA-P10	BSA	3	"Most definitely… I thought of it as separate worlds, but seeing them come together was really eye-opening."	Integrative insight

6. BSA High School Workshop (post-Surveys)

Participant ID	Workshop	Strand	Quote	Theme
SUN-S1	Sunspots survey	3	"The animations showing what was happening visually."	Visual explanation
SUN-S2	Sunspots survey	3	"The animations were cool."	Enjoyment
SUN-S3	Sunspots survey	3	"The drawing part was fun and kept me engaged."	Engagement / hands-on
SUN-S4	Sunspots survey	3	"The animations prior made me more interested because I understood it more."	Interest + understanding
SUN-S5	Sunspots survey	3	"Having a visual guide and being able to draw on it helped me understand science more."	Visual scaffold / drawing
SUN-S6	Sunspots survey	3	"I'm not sure because I don't really know how to connect them; they just connect in my head."	Tacit connection / uncertainty
SUN-S7	Sunspots survey	3	"Not really because the activities didn't feel like they engaged me in science through art."	Limitation / critical feedback
SUN-S8	Sunspots survey	3	"When they showed us science through animation to understand better."	Perceived clarity
SUN-S9	Sunspots survey	3	"Learning about the jets that can destroy most things but also create life."	Fascination / ambivalence
SUN-S10	Sunspots survey	3	"I learned that science through animation is better."	Preference for multimodal learning
SUN-S11	Sunspots survey	3	"I learned sunspots are patches of energy and heat."	Content learning

SUN-S12	Sunspots survey	3	"Today, nothing because nothing was taught… I have little interest in science, but more interest in research and discovery… and the depths of the ocean."	Resistance / alternate interests

7. Padova Workshop (Students / Young Adults – Sunspots - post-Surveys)

Participant ID	Workshop	Strand	Quote	Theme
PAD-P1	Padova	3	"Animation can be in every aspect of our lives. Yes, even in science. Without animation, we could not study or see the invisible."	ART+SCI / visualising the invisible
PAD-P2	Padova	3	"I learned something about solar spots and magnetic field… every time I listen and think about it, drawing for example, I think I learn something new."	Curiosity / iterative learning
PAD-P2	Padova	3	"While I draw… it helps me to think, to process the information."	Reflective drawing / cognition
PAD-P2	Padova	3	"We learn also by doing. It is very important. And the creativity can boost this learning."	Learning-by-doing / creativity
PAD-P3	Padova	3	"I don't think every kind of art has to be closed in itself. Communication between art and science is fundamental for increasing our knowledge."	Interdisciplinary thinking
PAD-P4	Padova	3	"Before this presentation, I thought animation was just Disney films. Now I see it is very useful for science."	Expanded concept of animation
PAD-P4	Padova	3	"Sometimes we cannot see invisible things… using animation we can see perhaps what they are like."	Visualising unobservable phenomena
PAD-P5	Padova	3	"It's not scientific, but I think that's okay… these stories help. Our parents told us this story when we were children."	Culture / mythology and science

PAD-P5	Padova	3	"This makes me feel better and make me feel happy… we are stressed with the studies… this fills our life."	Wellbeing / emotional relief
PAD-P6	Padova	3	"I learned how animation of science knowledge helps children to learn. It's very fun."	Pedagogical value
PAD-P7 (group)	Padova	3	"It was interesting because I didn't know anything about the Sun… it helped us to understand better, even for people that don't really know about science."	New knowledge / accessibility
PAD-P8	Padova	3	"Doing animation on something that is real and alive… it's very special."	Liveliness / connection
PAD-P8	Padova	3	"While drawing on it… somehow it feels more connected. Through animation it gives movement to something that has no limbs."	Embodiment / connection
PAD-P9	Padova	3	"When someone mixes science and cinema, it's perfect… I really love movies and animation with science."	Science–cinema affinity
PAD-P10	Padova	3	"When there's animation, it makes it easier, because it's more fun. So you get a better understanding."	Enjoyment → understanding

8. Montgomery Library Teen Workshop – Group Interview (Jupiter)

Participant ID	Workshop	Strand	Quote	Theme
TW-P6	Teen workshop	3	"Animation is so fun… if you use animation for educational purposes… it could really teach people our age or even younger to enjoy science."	Engagement / age-relevant pedagogy
TW-P6	Teen workshop	3	"It's not the animation itself that teaches me the science, but because animation is involved, I'm more engaged and more ready to learn."	Engagement vs. content
TW-P6	Teen workshop	3	"Kids like to be creative… having a creative aspect in education really helps."	Creativity as learning tool

TW-P6	Teen workshop	3	"Some of my friends have a hard time paying attention in school… this kind of learning could really help them."	Inclusivity / attention
TW-P6	Teen workshop	3	"I never thought people used animations to simulate planets and movements… it changed how I see NASA and science."	New perception of science practice
TW-P6	Teen workshop	3	"It made me think of creativity as a learning tool."	Meta-reflection on pedagogy
TW-P6	Teen workshop	3	"I'd have a higher tendency to want to learn something when animation is involved."	Motivation
TW-P6-peer	Teen workshop	3	"I learned that I want to do something in aerospace… learning about gravitational constants makes me passionate about science."	Career aspiration / identity
TW-P4	Teen workshop	3	"Yes, definitely… I've seen how [art and science] can connect."	Art–science connection
TW-P4	Teen workshop	3	"Maybe something with NASA and storytelling."	Narrative science communication

Appendix B: Survey Instruments and Data

B.1.Baltimore School for the Arts_ Teens survey

BSA Teens survey before

PARTICIPANT FORM

Research Ethics Committee Reference Number: 23/LSA/005

What is the purpose of the study?

I am currently pursuing a practice-based PhD at LJMU in collaboration with the Transart Institute for Creative Research. The focus of my research project is on astronomy outreach and animation, specifically investigating how animation can effectively engage teenagers in astronomy. Your responses will be kept private and will help improve astronomy outreach through animation.

For more information about this study, please check the information sheet at the bottom of this form.

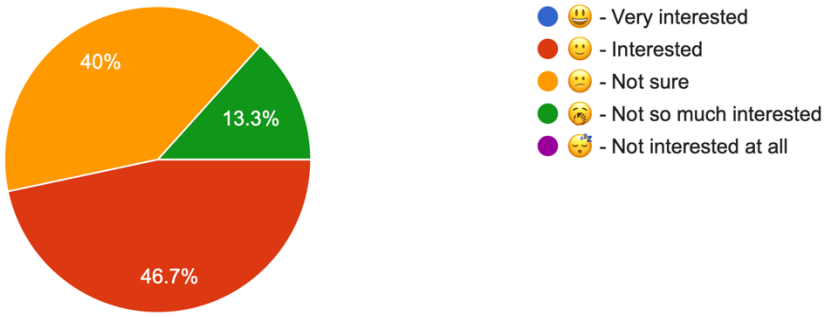
If you agree to be part of this study, please fill up the consent form if you are 16 and above, if not, we will need Parental or Guardian Consent

We will be taking pictures and videos durig the workshop.

IF YOU DON'T WANT YOUR PHOTO TO BE TAKEN, LET US KNOW ASAP, THANKS!

How much are you interested in animation?

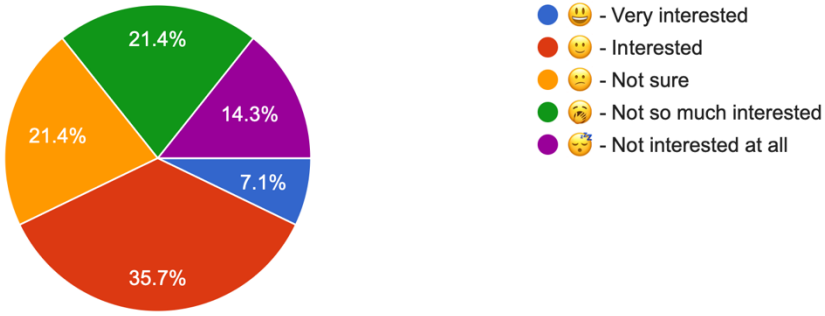
15 responses



1.

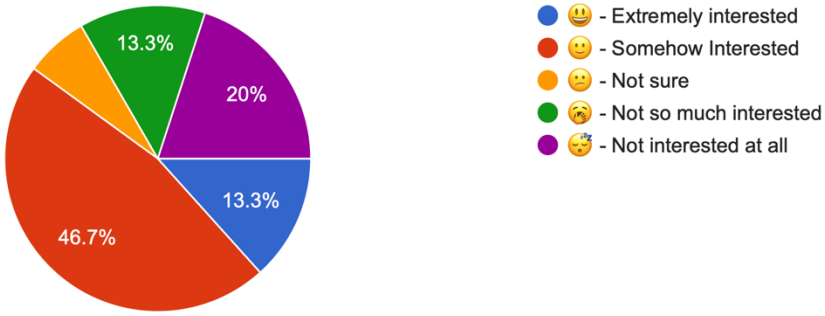
How much are you interested in science?

14 responses



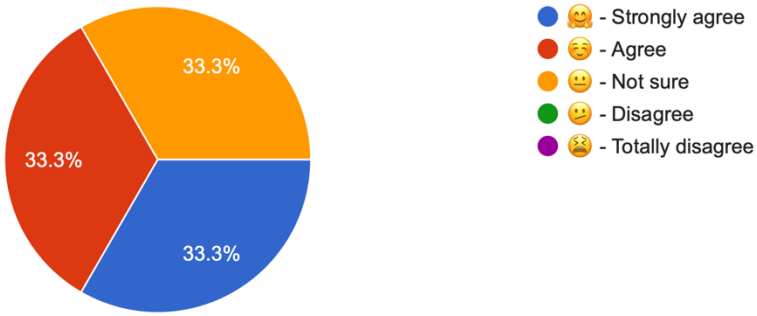
How much are you interested in astronomy?

15 responses



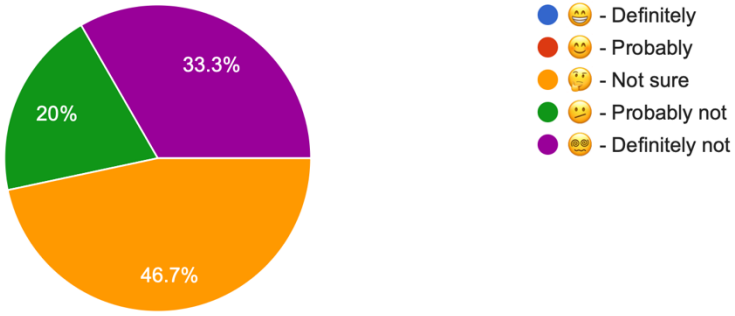
Do you think animated cartoons could help you learn interesting science facts?

15 responses



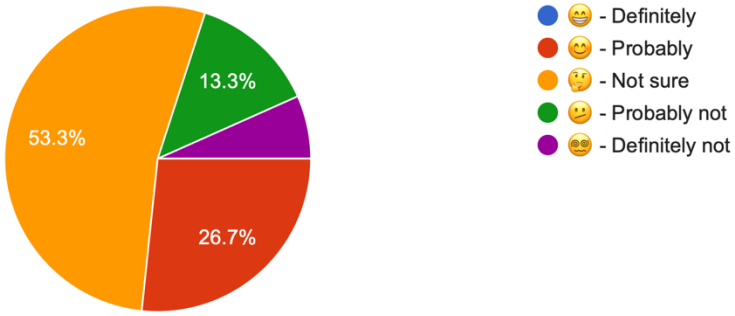
Would you consider a job in science in the future?

15 responses



Would you consider a job that mixes science and art?

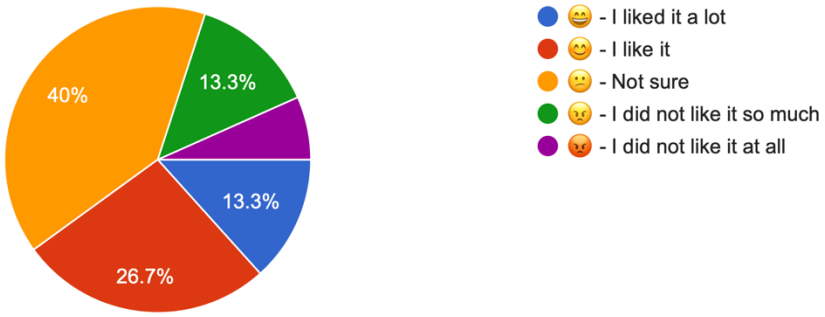
15 responses



BSA Teens survey After

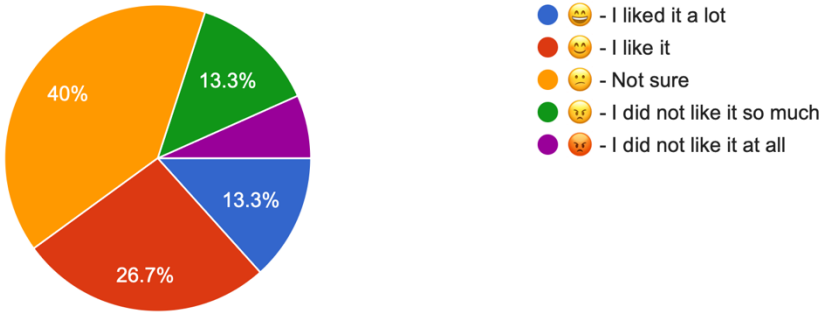
How much did you enjoy doing the astro-animation workshop?

15 responses



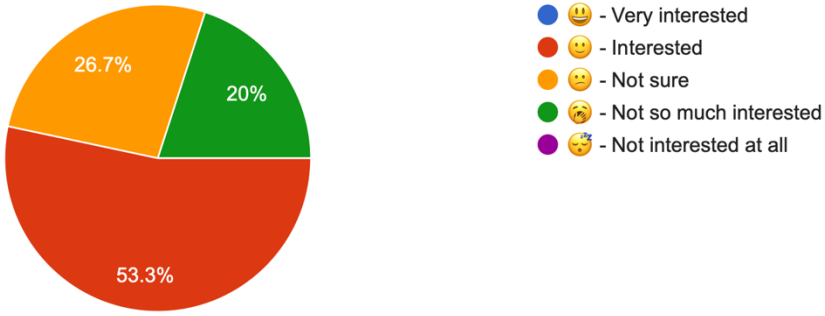
How much did you enjoy doing the astro-animation workshop?

15 responses



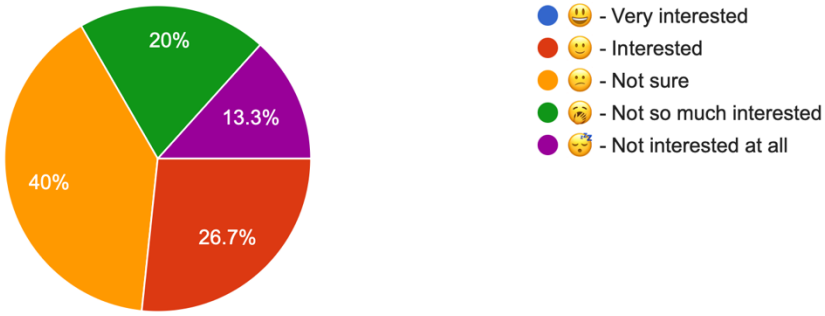
How much are you interested in animation?

15 responses



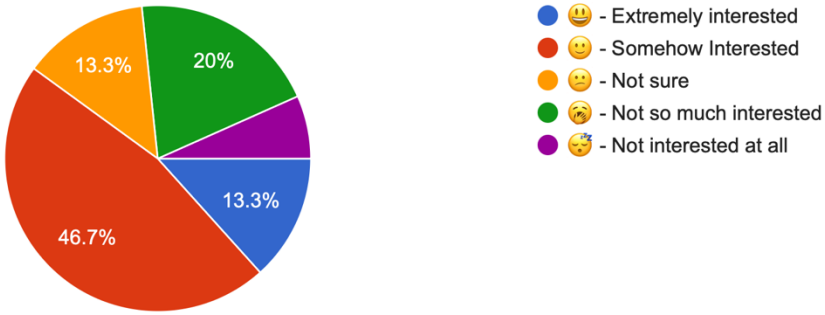
How much are you interested in science?

15 responses



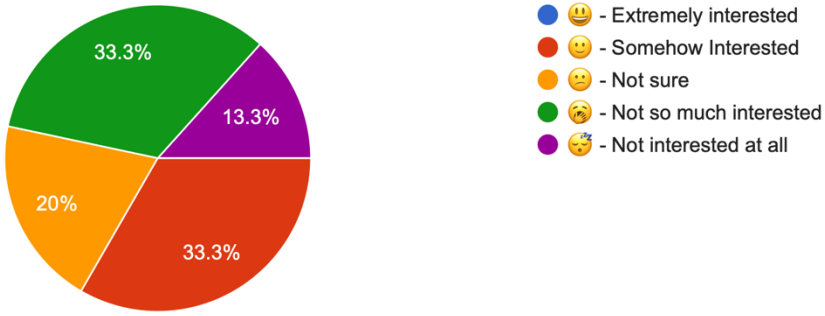
How much are you interested in astronomy?

15 responses



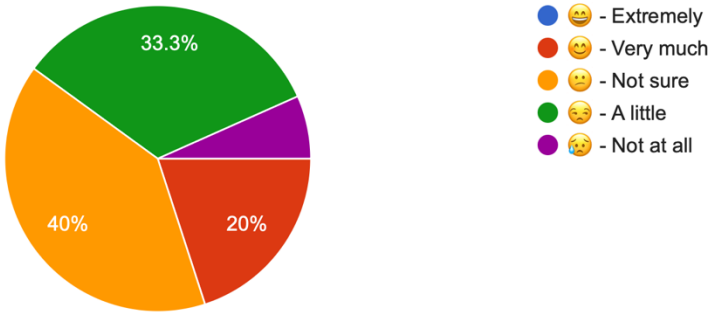
How interested are you in learning more about the astronomy topics we talked about in class?

15 responses



How much did the animation activities help you connect with science

15 responses



Can you describe a moment during the animation activities that made science more interesting for you?

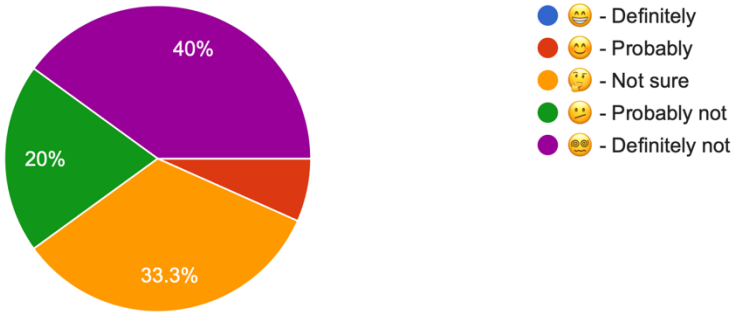
15 responses

The animations showing what was happening visually
Learning about the Jets that can destroy most things but also create life.
I can't recall a specific moment.
The animations prior made me more interested because I understood it more.
When they showed us science through animation to understand better.
No. I don't have any. I enjoyed the presentation parts but the actual animation wasn't very helpful or fun.
idk
Not really, no.

Not really because the activities didn't feel like they engaged me in science through art.
i was not here on that day
I'm not sure because I don't really know how to connect them, they just connect in my head.
the animations were cool
i liked the imagery on the slides
The drawing part was fun, and kept me engaged.
Having a visual guide and being able to draw on it helped me understand science more.

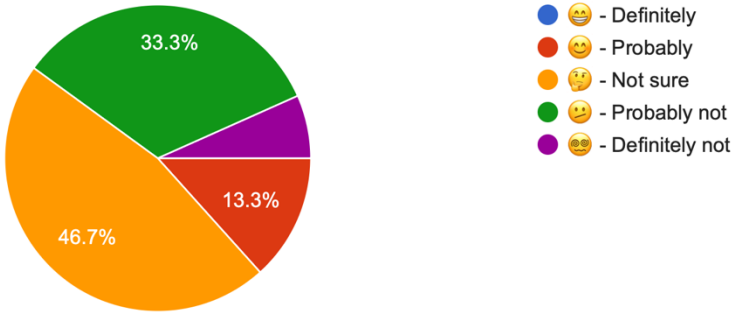
Would you consider a job in science in the future?

15 responses



Would you consider a job that mixes science and art?

15 responses



Please, tell us one thing you learned today 15 responses

I learned about gamma rays
Today, nothing because nothing was taught.
I learned about GRB explosions.

how gamma ray burst work
I learnd that science through animation is better
How big the sun is in comparison to the earth.
nothing
GRB's makes waves.
How a gamma ray burst happens
that i dont really like anmation
I learned that Galileo also worked with sunspots and animation.
that there are stars that orbit each other.
the swift telescope and GRBs
Gallilaio used animations
I learned sun-spots are patches of energy and heat.

Anything else you want to tell us? 13 responses

no
I have no interest in math math is science and so therefore i have little interest in science. However I do have in the research and discovery. I have more interest in the depths of the ocean.
I'd like to learn more about black holes.
nope!
No.
im not good at it
Nope
Not really

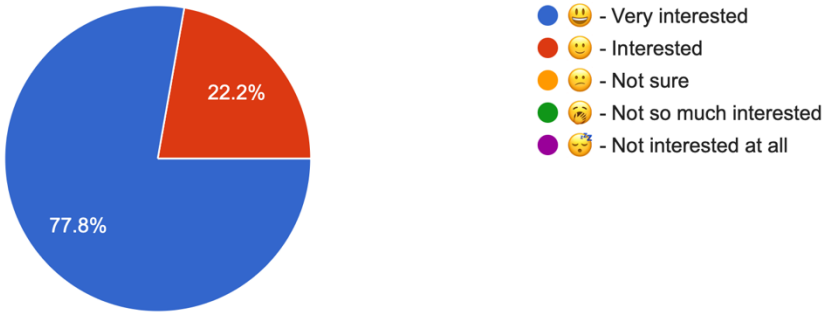
B.2. Pratt Library FAMILY- Survey Responses

Pratt Library FAMILY_BEFORE

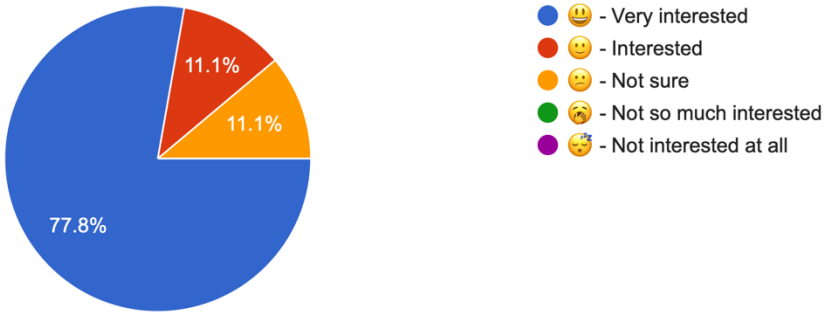
Flying by Pluto, Astro-Animation Workshop PRATT Library

PARTICIPANT FORM
Research Ethics Committee Reference Number: 23/LSA/005
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For more information about this study, please check the information sheet at the bottom of this form.
We will be taking pictures and videos during the workshop.
IF YOU DON'T WANT YOUR PHOTO TO BE TAKEN, LET US KNOW ASAP, THANKS!

How much are you interested in animation?
9 responses

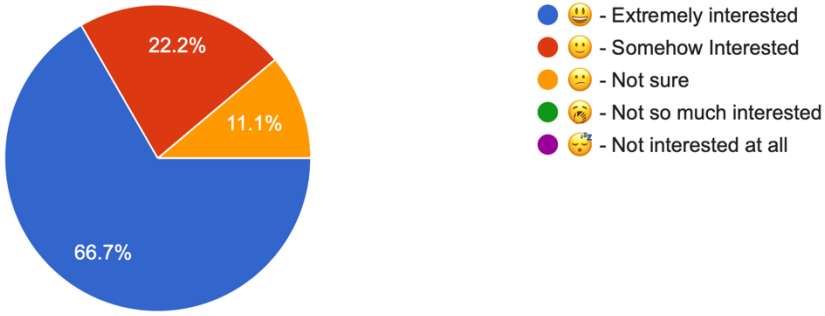


How much are you interested in science?
9 responses



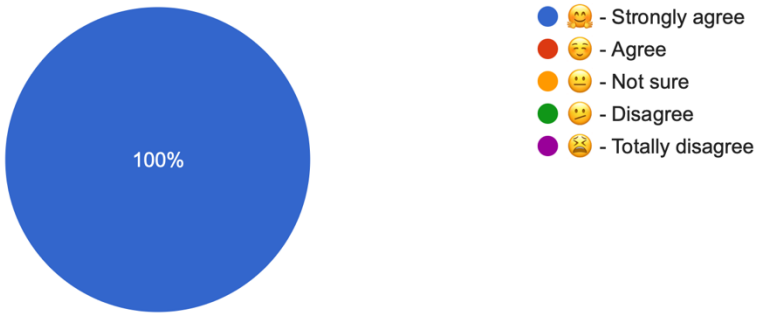
How much are you interested in astronomy?

9 responses



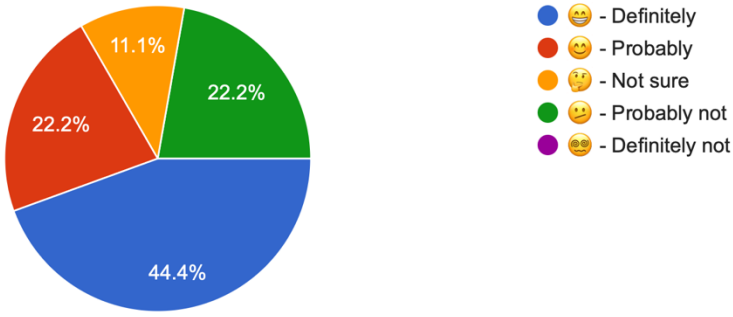
Do you think animated cartoons could help you learn interesting science facts?

9 responses



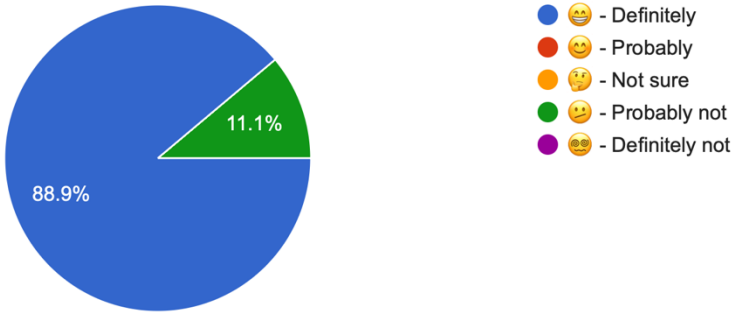
Would you consider a job in science?

9 responses



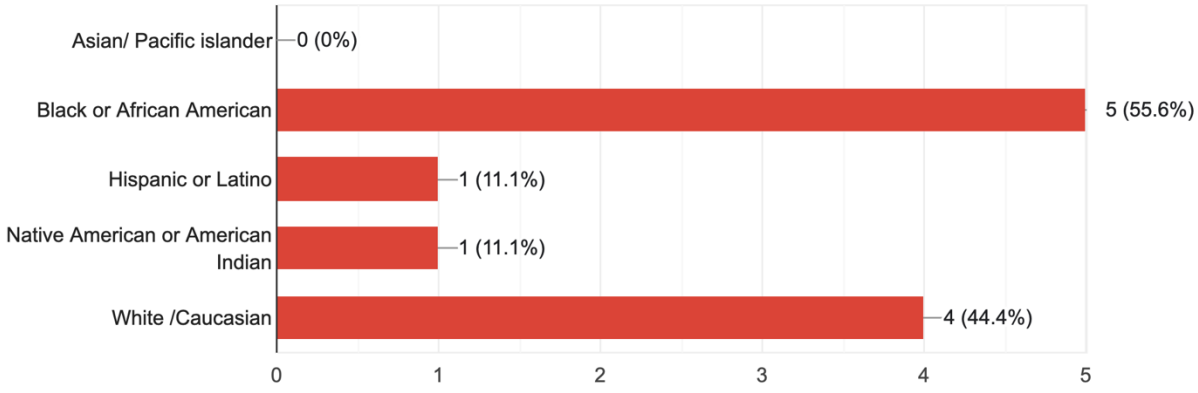
Would you consider a job that mixes science and art?

9 responses



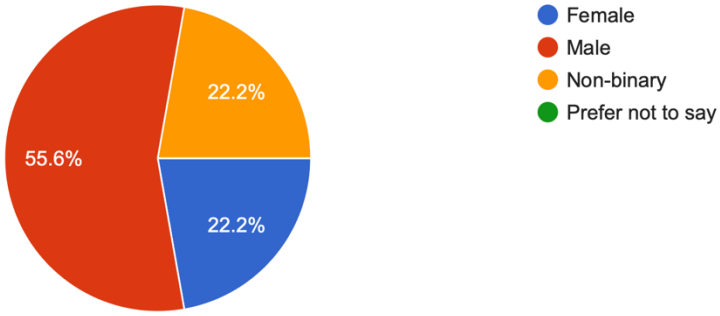
Are you….(check all that apply)

9 responses



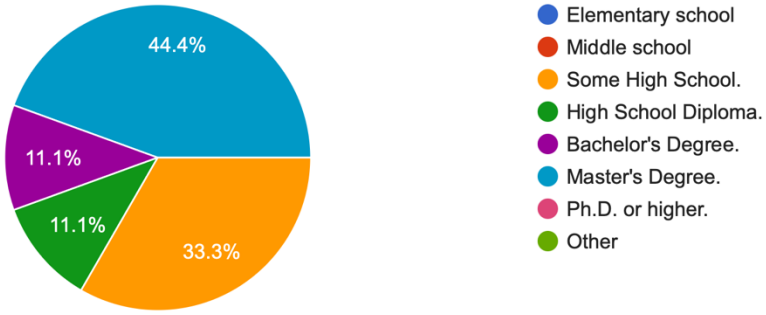
What is your gender?

9 responses



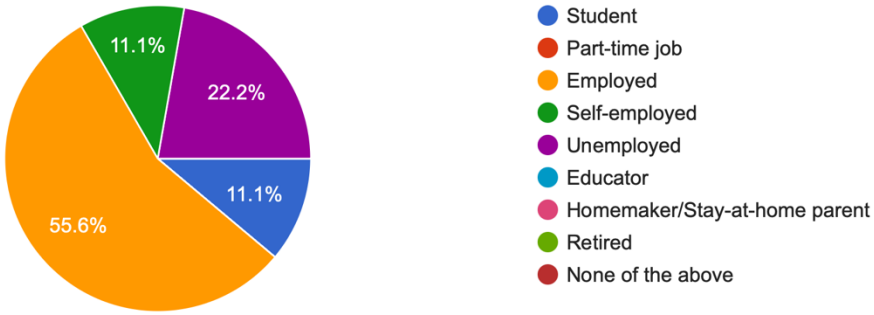
What is the highest degree or level of education you have completed?

9 responses



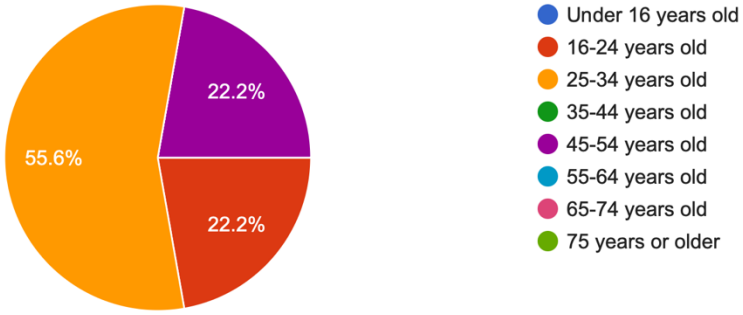
Occupation (check all that apply) What best describes your employment status?

9 responses



What is your age?

9 responses



Information sheet

You are being invited to take part in a research study. You do not have to take part if you do not want to. Please read this information, which will help you decide.

What is the purpose of the study?

I am currently undertaking a practice-based PhD at LJMU in collaboration with Transart Insitute for Creative Research and your responses will be very helpful for my research.

What will happen to me if I take part?

You will be invited to give your feedback on an astro-animation workshop toolkit. You will be asked to respond to the questions below via an anonymous survey

Will I be photographed or video /audio recorded, and how will the recorded media be used?

yes, unless you request not to be photographed or video recorded. It may be used in academic presentations.

Are there any benefits in taking part?

There will be no personal benefit to you from taking part in this study, however, you may find the astro-animations useful for your own teaching and research, and consider similar art-science approaches when engaging the public with your own research.

Payments, reimbursements of expenses or any other benefit or incentive for taking part

There will be no payment or any benefit or incentive for taking part in this study. Unfortunately, we cannot reimburse any expenses you may incur.

What will happen to the information/data provided?

The information you provide as part of the study is the **study data**. Any study data from which you can be identified (e.g. from identifiers such as your name, date of birth, audio recording etc.), is known as **personal data.** Your participation in this study will not involve the collection/use of personal data by the investigator. Your answers to the questions may be used in our research.

Whom do I contact if I have a concern about the study or I wish to complain?

If you have a concern about any aspect of this study, please contact *Mark Roughley*, and we will do our best to answer your query. You should expect a reply within 10 working days. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics Committee at Liverpool John Moores University who will seek to resolve the matter as soon as possible:

Chair, Liverpool John Moores University Research Ethics Committee; Email: FullReviewUREC@ljmu.ac.uk; Tel: 0151 231 2121; Research Innovation Services, Liverpool John Moores University, Exchange Station, Liverpool L2 2QP

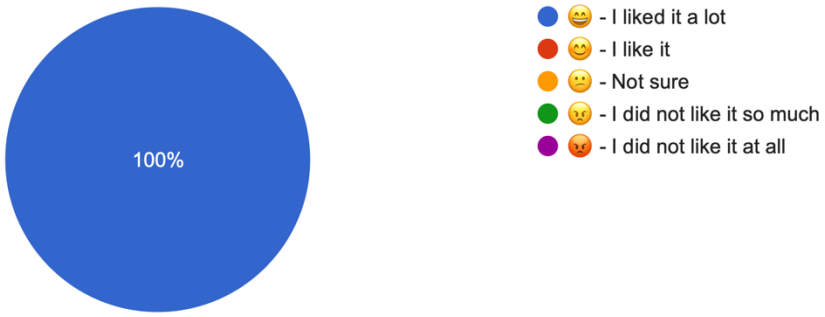
Principal Investigator: *Laurence Arcadias*
LJMU postgraduate research student
LJMU Email address: *l.arcadias@2022.ljmu.ac.uk*
LJMU School/of Art and Design
LJMU Central telephone number: +44 151 231 2121
Supervisor Name: *Mark Roughley*
LJMU Email address: *M.A.Roughley@ljmu.ac.uk*

If you are happy to participate, please complete this form

Pratt Library, FAMILY_AFTER

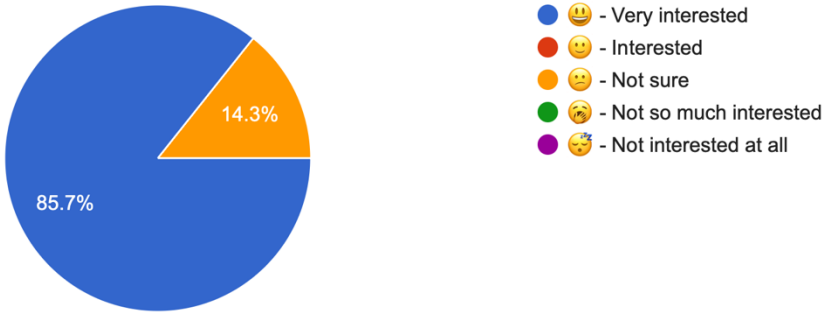
How much did you enjoy doing the astro-animation workshop?

7 responses



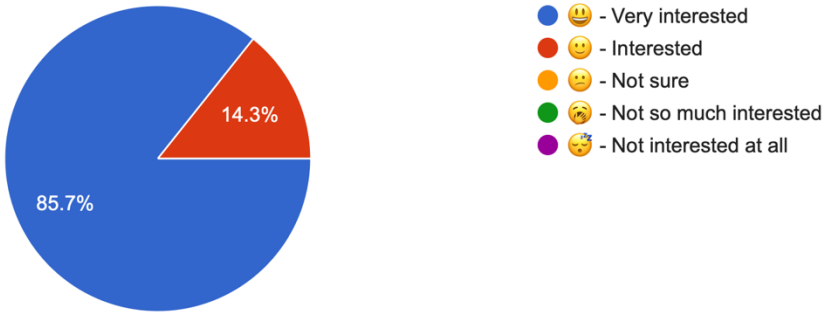
How much are you interested in science?

7 responses



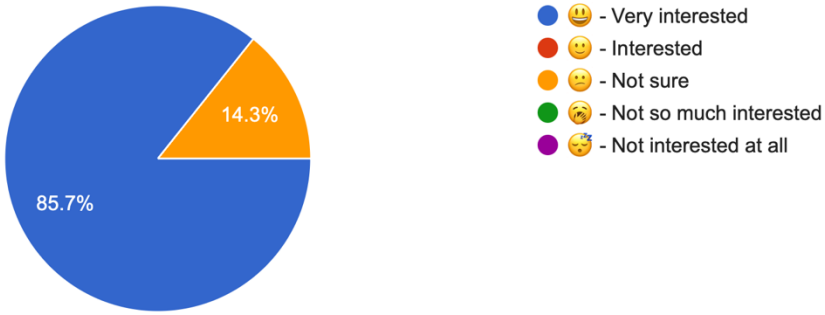
How much are you interested in animation?

7 responses



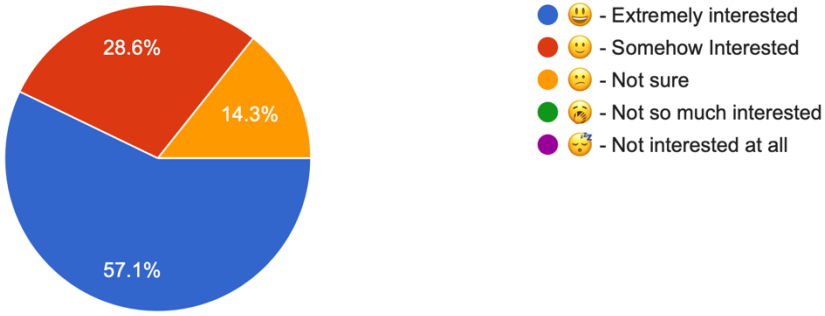
How much are you interested in science?

7 responses



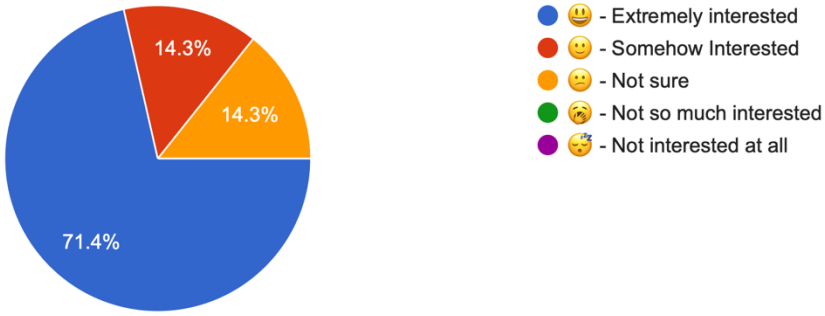
How much are you interested in astronomy?

7 responses



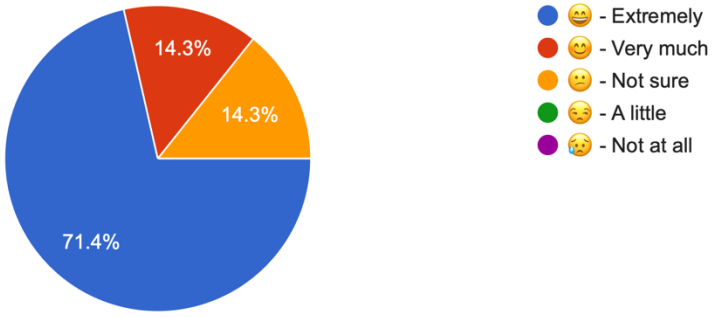
How interested are you in learning more about the astronomy topics we talked about at the library?

7 responses



How much did the animation activities help you connect with science

7 responses



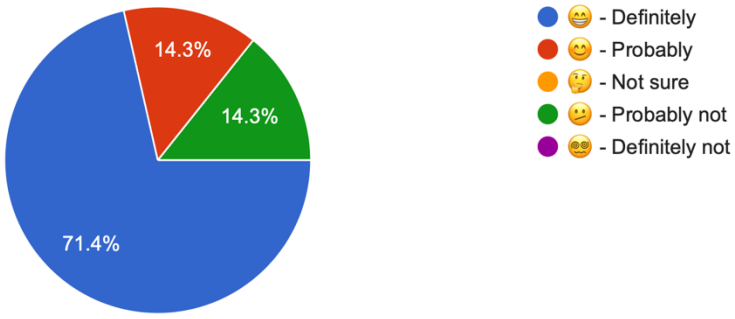
Can you describe a moment during the animation activities that made science more interesting for you?

6 responses

Learning about pluto
The process of creating our animation in stages helped conceptualize how space works.
Mixing animation and science together
Drawing animations on the planet we just learned about made it easier to retain the information. I learned that it takes Pluto about 250 yrs to rotate around the sun, so I drew my little guy having a blast and taking his time on Pluto.
It was a fun way to connect ideas of science with ideas of animation
Drawing and asking bout pluto

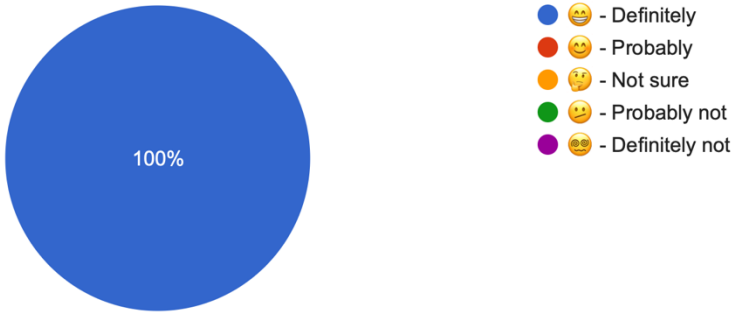
Would you consider a job in science in the future?

7 responses



Would you consider a job that mixes science and art?

6 responses



Please, tell us one thing you learned today :6 responses

About animation frames and how 12 add up to a second
Pluto is still a planet! - BUT, I understand why it was demoted.
That pluto was dwarf plant
My gold jewelry is possibly made from neutron stars that have collided.
that we need to get back into animation again
Pluto use to be a planet

Anything else you want to tell us? 6 responses

I'd love to learn more about it!
N/A
I just love it
I throughly enjoyed this class and hope it's accessible to young kids in schools!
thank you for this experience
It's fun like bill Nye

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Are there any benefits in taking part?

There will be no personal benefit to you from taking part in this study, however, you may find the astro-animations useful for your own teaching and research, and consider similar art-science approaches when engaging the public with your own research.

Payments, reimbursements of expenses or any other benefit or incentive for taking part

There will be no payment or any benefit or incentive for taking part in this study. Unfortunately, we cannot reimburse any expenses you may incur.

What will happen to the information/data provided?

The information you provide as part of the study is the **study data**. Any study data from which you can be identified (e.g. from identifiers such as your name, date of birth, audio recording etc.), is known as **personal data.** Your participation in this study will not involve the collection/use of personal data by the investigator. Your answers to the questions may be used in our research.

Whom do I contact if I have a concern about the study or I wish to complain?

If you have a concern about any aspect of this study, please contact *Mark Roughley*, and we will do our best to answer your query. You should expect a reply within 10 working days. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics Committee at Liverpool John Moores University who will seek to resolve the matter as soon as possible:

Chair, Liverpool John Moores University Research Ethics Committee; Email: FullReviewUREC@ljmu.ac.uk; Tel: 0151 231 2121; Research Innovation Services, Liverpool John Moores University, Exchange Station, Liverpool L2 2QP

Principal Investigator: *Laurence Arcadias*
LJMU postgraduate research student
LJMU Email address: *l.arcadias@2022.ljmu.ac.uk*
LJMU School/of Art and Design
LJMU Central telephone number: +44 151 231 2121
Supervisor Name: *Mark Roughley*
LJMU Email address: *M.A.Roughley@ljmu.ac.uk*

If you are happy to participate, please complete this form

Pratt Library Family Survey Responses

Participant ID	Interest in Animation (1-5)	Interest in Science (1-5)	Interest in Astronomy (1-5)	Belief: Animation Helps Learning (1-5)	Future Job in Science (Yes/No)	Job Combining Science + Art (Yes/No)
1	4	5	5	5	4	5
3	5	3	3	4	2	2
2	4	4	4	4	2	4
5	5	5	4	5	5	3
6	4	5	5	5	5	2
8	4	5	4	5	5	4
9	5	5	5	5	5	5

Survey Before

Participant ID	Enjoyed Workshop (1-5)	Enjoyed Astronomy Talk (1-5)	Interest in Animation (1-5)	Interest in Science (1-5)	Interest in Astronomy (1-5)	Interest in Jupiter (1-5)	Belief: Animation Shows Science Well (1-5)	Memorable Moments	What They Learned	Comments	Future Job in Science (Yes/No)	Job Combining Science + Art (Yes/No)
2	5	5	4	4	4	4	4				3	3
5	4	4	4	4	3	3	5	there is much more in animation than science, than math	Black holes release kinetic and potential energy	thank you for this information	4	3
6	5	4	4	5	5	4	3	when we were given the Jupiter prints	gravity	yhank you for this opportunity	5	4
8	5	5	4	5	5	4	5	drawing, editing the animations	how animation can help kids learn	thank you	5	5
9	5	5	5	5	5	4	4	an activity during the animation, the animation of jupiter rotation	gravity exists in space	looking for internship	5	4

Survey After

B.3 Montgomery Teens surveys

Montgomery Teens_Survey-Before

Participant ID	Date	Interest in Animation (1-	Interest in Science (1-5)	Interest in Astronomy (1-5)	Belief: Animation Helps Learning (1-5)	Future Job in Science (Yes/No)	Job Combining Science + Art (Yes/No)	Notes
1		4	5	5	5	4	5	
3		5	3	3	4	2	2	
2		4	4	4	4	2	4	
5		5	5	4	5	5	3	
6		4	5	5	5	5	2	
8		4	5	4	5	5	4	
9		5	5	5	5	5	5	

Montgomery Teen -Survey- After

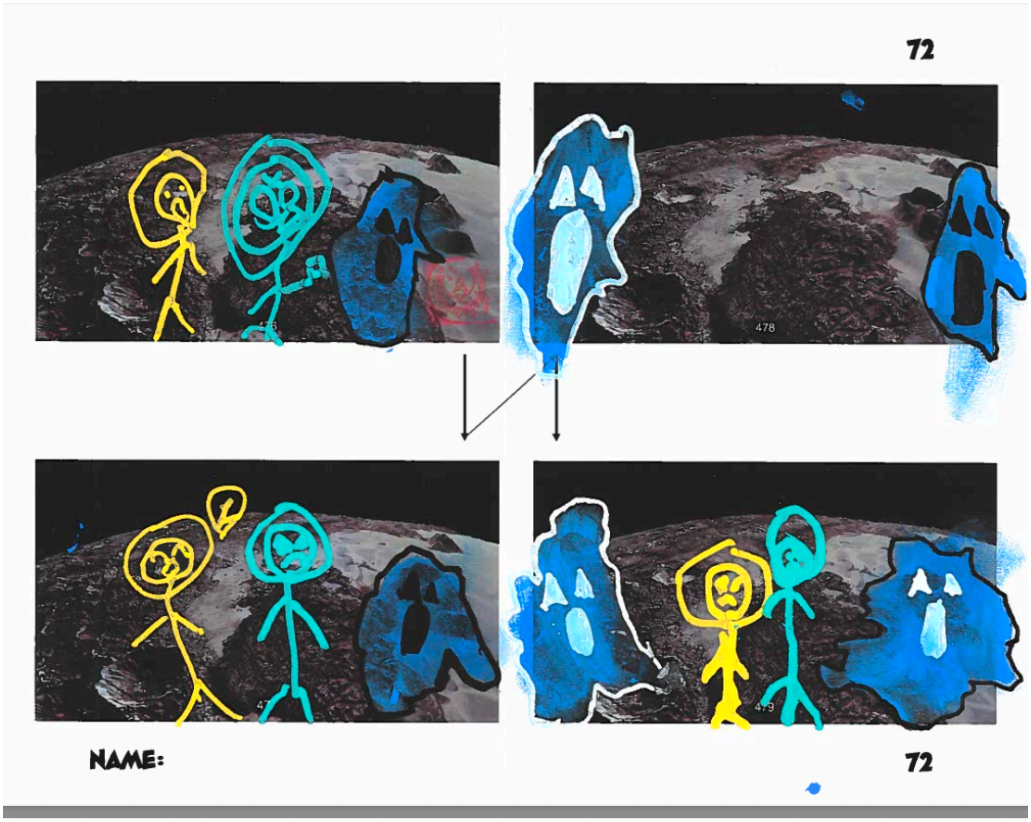
Participant ID	Enjoyed Workshop (1-5)	Enjoyed Astronomy Talk (1-5)	Interest in Animation (1-5)	Interest in Science (1-5)	Interest in Astronomy (1-5)	Interest in Jupiter (1-5)	Belief: Animation Shows Science Well (1-5)	Memorable Moments	What They Learned	Comments	Future Job in Science (Yes/No)	Job Combining Science + Art (Yes/No)
2	5	5	4	4	4	4	4				3	3
5	4	4	4	4	3	3	5	there is much more in animation than science, than math	Black holes release kinetic and potential energy	thank you for this information	4	3
6	5	4	4	5	5	4	3	when we were given the Jupiter print	gravity	yhank you for this opportunity	5	4
8	5	5	4	5	5	4	5	drawing, editing the animations	how animation can help kids learn	thank you	5	5
9	5	5	5	5	5	4	4	an activity during the animation, the animation of jupiter rotation	gravity exists in space	looking for internship	5	4

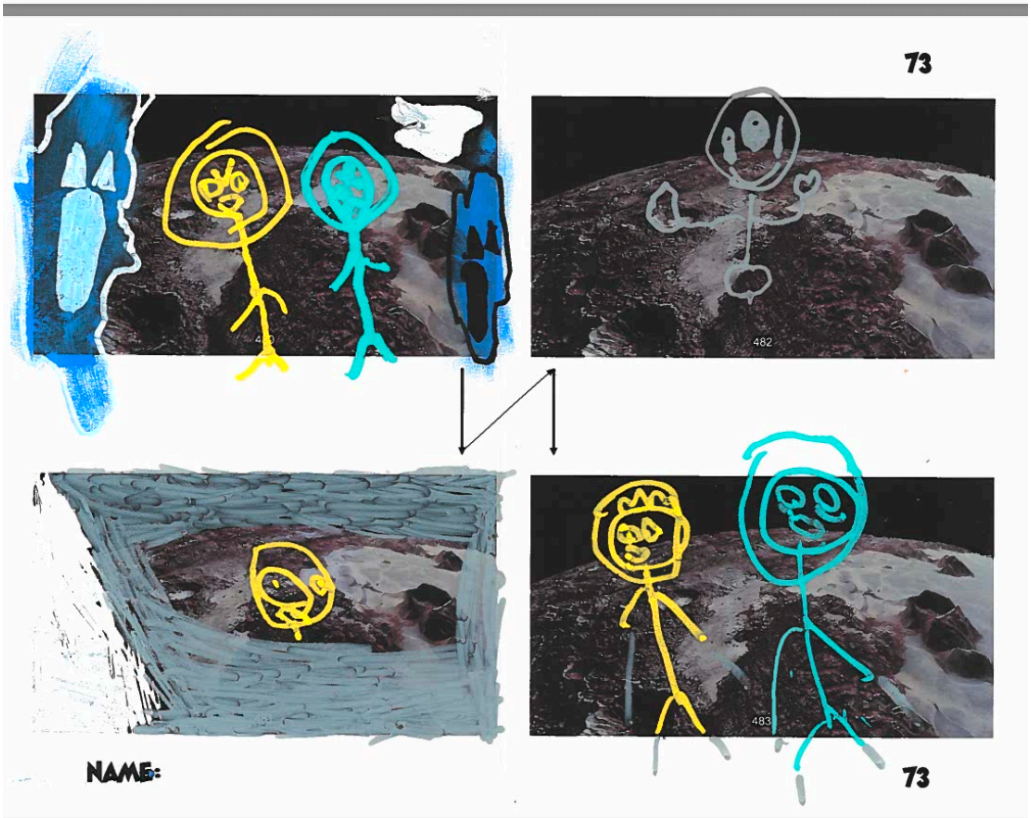
Appendix C: Practice-Based Outputs and Supporting Materials

C.1 Screenshots of student animations:

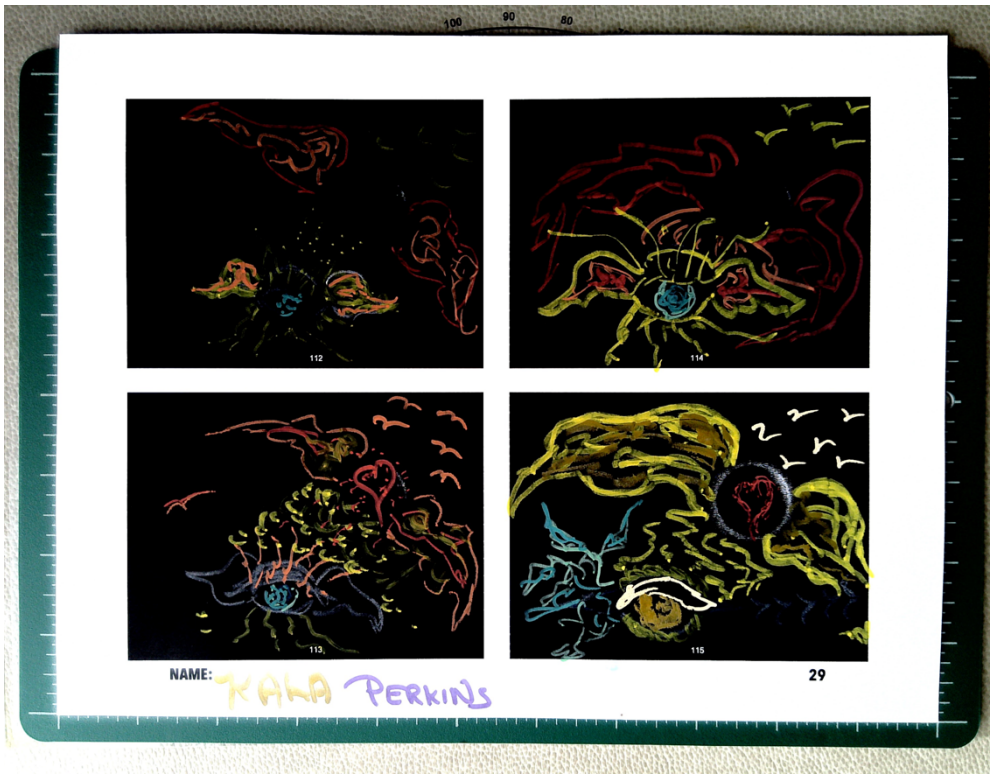


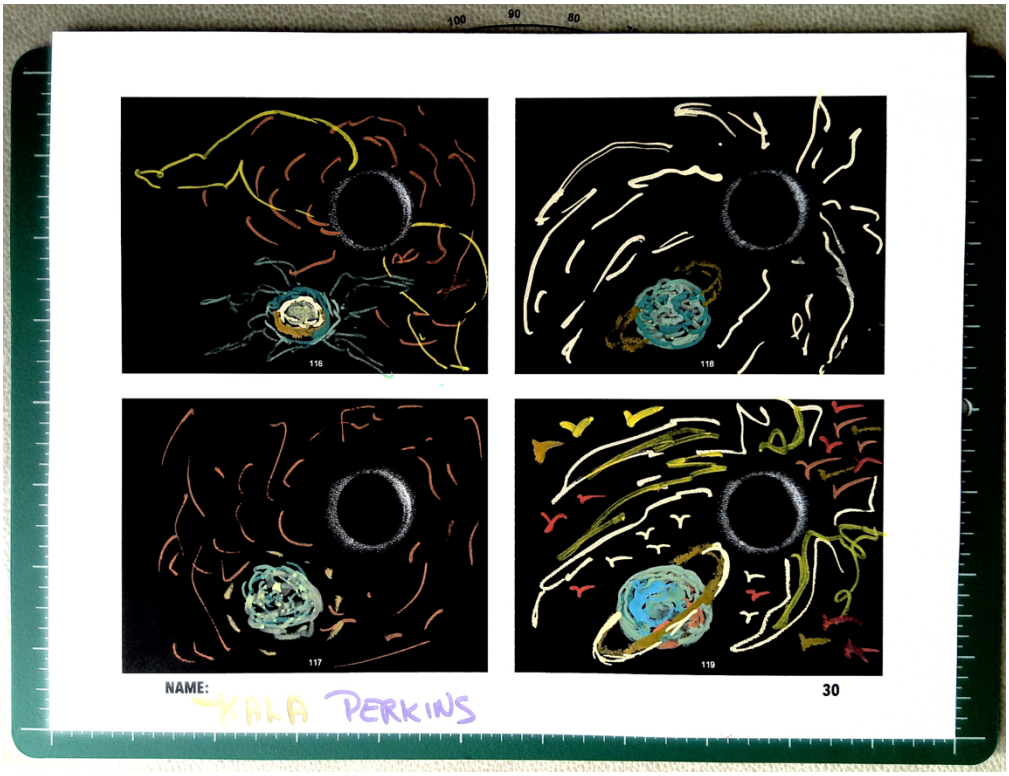
Strange News from Pluto- Pratt Library Family +LJMU+Transart


72
478
NAME:
72


73
482
483
NAME:
73

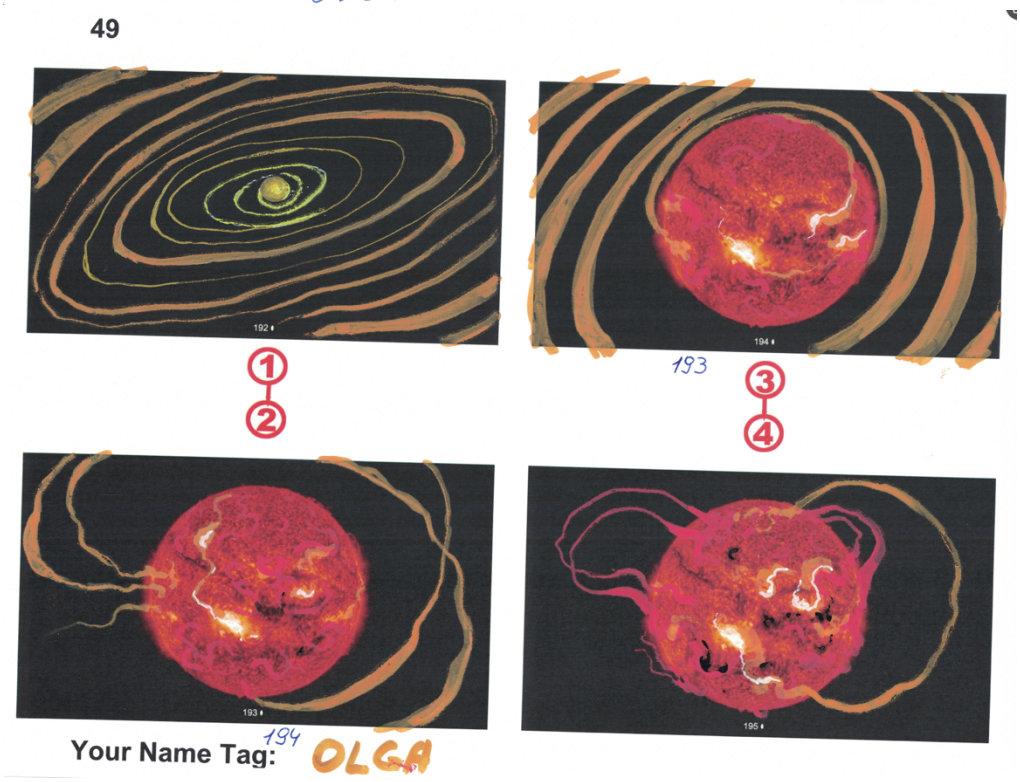
The Eclipse- AAA Head meeting Scientists





Sunspot: BSA +Padova





C.2 Music permissions:

Flight of the Bumblebee- Rimsky-Korsakov

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Rimsky-Korsakov, Nikolai - Flight of the Bumblebee (Arranged for Strings) - (Commercial License) SQ7616111 Price: $5 Qty: 1 €5.00 / Item	€5.00

Appendix D: Ethical Oversight, Consent Procedures, and Data Governance

This appendix provides a detailed account of the ethical frameworks, governance processes, and safeguarding measures underpinning the Astro-animation research project. It expands on the summary presented in Section 2.5 by documenting consent procedures, data management protocols, attribution practices, and institutional responsibilities in full, ensuring transparency, accountability, and compliance with LJMU and GDPR requirements. It supplements the summary presented in Section 2.5 by documenting procedural detail required for transparency, accountability, and institutional compliance.

Ethical Oversight and Governance

This research adhered to the Liverpool John Moores University (LJMU) Code of Practice for Research (2020) and received full approval from the University Research Ethics Committee (UREC) prior to commencement (Ethics Reference No. 23/LSA/006). Ethical principles of respect, transparency, inclusivity, informed consent, and participant welfare were upheld throughout all strands of the study. These principles guided all aspects of recruitment, facilitation, data collection, and representation.

Informed Consent and Participant Communication

All participants were provided with detailed information outlining the study's aims, procedures, potential risks and benefits, and the voluntary nature of participation, and were informed of their right to withdraw at any time without consequence. Scientists and expert contributors (Strands 1 and 2) gave written consent prior to involvement, while public workshop participants (Strand 3) received age-appropriate information sheets and consent or assent forms distributed by gatekeeping organisations that also confirmed participant eligibility in accordance with safeguarding protocols. Where participants were minors, parents or guardians provided written consent through the partner institute.

Data Management and Anonymisation

All data were collected, processed, and stored in accordance with the UK General Data Protection Regulation (GDPR) and LJMU's Data Management Policy. Public workshop data were anonymised, with neutral identifiers used to link pre- and post-survey responses without including personal names or identifiable details. For minors, photographs and video recordings focused exclusively on hands and creative outputs rather than faces. Digital files were stored securely on password-protected drives accessible only to the researcher and supervisors, and consent forms and identifiable information were stored separately from research data to ensure confidentiality throughout the project.

Attribution and Recognition

Participants were offered the choice of anonymity or recognition, depending on the context of their contribution. In Strand 1, NASA scientists provided consent that included naming and visual representation in composite images and in the final film *The Movements of the Universe*. In Strand 2, expert participation was voluntary, with anonymity maintained unless attribution was explicitly requested. In Strand 3, no identifying personal data were collected, and anonymised reporting and safeguarding were managed through partner institutions. Where public screenings or online compilations were produced, contributors could opt in to receive credit, with permissions specifying the scope, duration, and conditions of future use.

LIVERPOOL JOHN MOORES UNIVERSITY

PARTICIPANT CONSENT FORM Teens aged 16-18

Study title: AN ASTRO-ANIMATION WORKSHOP FOR TEENS to inspire youth in steam
Research Ethics Committee Reference Number: **23/LSA/006**

Principal Investigator: *Laurence Arcadias*
LJMU postgraduate research student
LJMU Email address: *l.arcadias@2022.ljmu.ac.uk*
LJMU School: *Liverpool School of Art and Design*
LJMU Central telephone number: 0151 231 2121
Supervisor Name: *Mark Roughley*
LJMU Email address: *M.A.Roughley@ljmu.ac.uk*

Please read the statements below. If you are happy with all of the statements, return this form in an email and send it to me at l.arcadias@2022.ljmu.ac.uk

This will be considered to constitute giving your consent to participate in the study.

If you have any questions about the study or the statements below, please do not hesitate to contact me.

1.	I confirm that I have read the information sheet for the above study, or it has been read to me. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2.	I understand what taking part in the study involves	
3.	I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions I can withdraw from the study at any time, without giving a reason and without penalty or my legal rights being affected.	
4.	I agree to be observed during the study	
5.	I agree to be interviewed and video recorded for 5 to 10 minutes	
6.	I agree that video recordings/ photographs can be taken of me during the study. (Participants are free at any time to decline to be video recorded/ photographed – whilst continuing to participate in the study)	YES / NO
7.	I understand who will have access to personal data provided, how the data will be stored and what will happen to the data at the end of the project.	
10.	I agree for my contact details to be stored for the purpose of contacting me about future studies and I understand that agreeing to be contacted does not oblige me to participate in any further studies	YES / NO
11.	I understand that personal data will be retained beyond the duration of the study	
12.	I agree that photographs and recordings taken of me may be used in the final report and any further outputs.	YES / NO
13.	I agree to take part in this study	