CREATIONS Developing an Engaging Science Classroom	D2.2 Essentials of Creativity-enriched IBSE Pedagogy

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CREATIONS aims to demonstrate innovative approaches and activities that involve teachers and students in Scientific Research through creative ways that are based on the Arts and focus on the development of effective links and synergies between schools and research infrastructures in order to spark young people's interest in science and in following scientific careers. The foundation for this project is presented within Work Package 2 in five deliverables D2.1 (The features of inquiry learning: theory, research and practice), D2.2 (Essentials of creativity-enriched IBSE pedagogy), D2.3 (Effective learning environments for inquiry learning and teaching), D2.4 (Professional development of Educators: Considerations and Strategies) and D2.5 (A framework for identifying creative best practices in inquiry-based science education).

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This deliverable will present strategies for Creativity-enriched Inquiry as part of Scientific Literacy

Section 1 and Section 2 introduce the deliverable and explain how the CREATIONS features are embedded into IBSE practice. This is presented through a honeycomb structure to show how the cycle is connected and that the Arts and creative practice can permeate through at any stage in the cycle. Section 3 presents the CREATIONS toolkit and suggested activities to further demonstrate the CRNS features in both an embodied and practical way. Section 4 details the CERN case study of existing good practice and draws the reader to where the features are explicitly present. Section 5 explains how UoE can provide implementation support and further resources to help with this can be found in section 7.

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Acknowledgements

With thanks to Angelous Alexopoulos for taking the time to write the CERN (European Organization for Nuclear Research) Case Study.

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1. Introduction

This deliverable shares strategies and activities for Creativity-enriched Inquiry as part of Scientific Literacy. It demonstrates how the CREATIONS features interact with the IBSE cycle and presents the CREATIONS toolkit which is the means to facilitating this understanding of the features. Alongside explaining the toolkit this deliverable includes Implementation strategies for embedding the features via the toolkit across the consortium.

It is intended that the toolkit will support the Demonstration activities in Work Package 5. The exercises contained within the toolkit have been designed as a way for the facilitators and teachers to bring out the CREATIONS features as part of their Interdisciplinary practice; to bring the CREATIONS features alive. Further information regarding the CREATIONS features can be found in Deliverable D2.1 'The features of inquiry learning: theory, research and practice' (Chappell, Hetherington, Ruck Keene and Slade, 2016). The features are a series of connected teaching and learning principles developed from a review of current literature and existing good practice, which Chappell et al (2016) propose would be evident in creative science pedagogy.

The toolkit, within this Deliverable 2.2, has been designed to be equally applicable within school-based activities, activities that promote school-science centre and museum collaboration and activities that promote school-research centre collaboration.

To this end the deliverable contains a Case Study example from CERN, the European Organization for Nuclear Research, which articulates the IBSE processes, CREATIONS features and arts/science integration that the CREATIONS project is seeking to promote

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and sustain. This particular Case Study was chosen because it incorporates both school-based activities and school-research centre collaboration.

Finally, the deliverable articulates the implementation strategy for embedding the CREATIONS features and arts/science integration within the CREATIONS Demonstrators. Ultimately this will be the responsibility of all consortium partners to embed within their practice.

Throughout, the deliverable contains photographic and film examples.

The appendices contain the resources for the toolkit. They are also available here:[1]

[1] A web link to the resources will be inserted once the CREATIONS website is live

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2. Embedding the CREATIONS features within IBSE Practice

This section of the deliverable suggests how the CREATIONS features are present in creative IBSE practice. Using the table from section 6 of D2.1 (Chappell et al, 2016) we have developed a honeycomb structure to visually display how all the sections within the toolkit are connected and how the CREATIONS features permeate throughout by showcasing questions students, young people, teachers and scientists / researchers / artists might ask as they engage with the process. The CREATIONS features are highlighted in blue and *italicised* to further highlight and explain how the features are potentially present within each stage.

Each honeycomb is broken into six boxes, the first box (Black) describes a stage of the IBSE cycle e.g. 'Reflect', the next box (Blue) provides examples of questions children and young people might ask at this stage in the process. The third box (Blue) presents examples of questions teachers might ask to support the stage of enquiry. The following three boxes follow the cycle of three different experiments or activities in each of the Red, Purple and Green boxes. The Red boxes demonstrate an activity about forces and centrifugal forces. Following the IBSE cycle it presents how a young person might start with the **Question** stage 'What are forces, what is a centrifugal force, can you see forces'. To collect **Evidence** for this investigate question they decide to drop some point on a round surface then spin it to see what happens. As you move through the honeycombs each red box details the next stage of the investigation. The Purple boxes illustrate an investigation using dance to explore speed. The Green boxes follow an investigation about materials and reaction rates.

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The questions in purple text in each honeycomb are prompts to enable the young person and teacher/facilitator to consider the bigger picture question 'How can creativity and the Arts be enhanced / integrated at this stage in the process?'

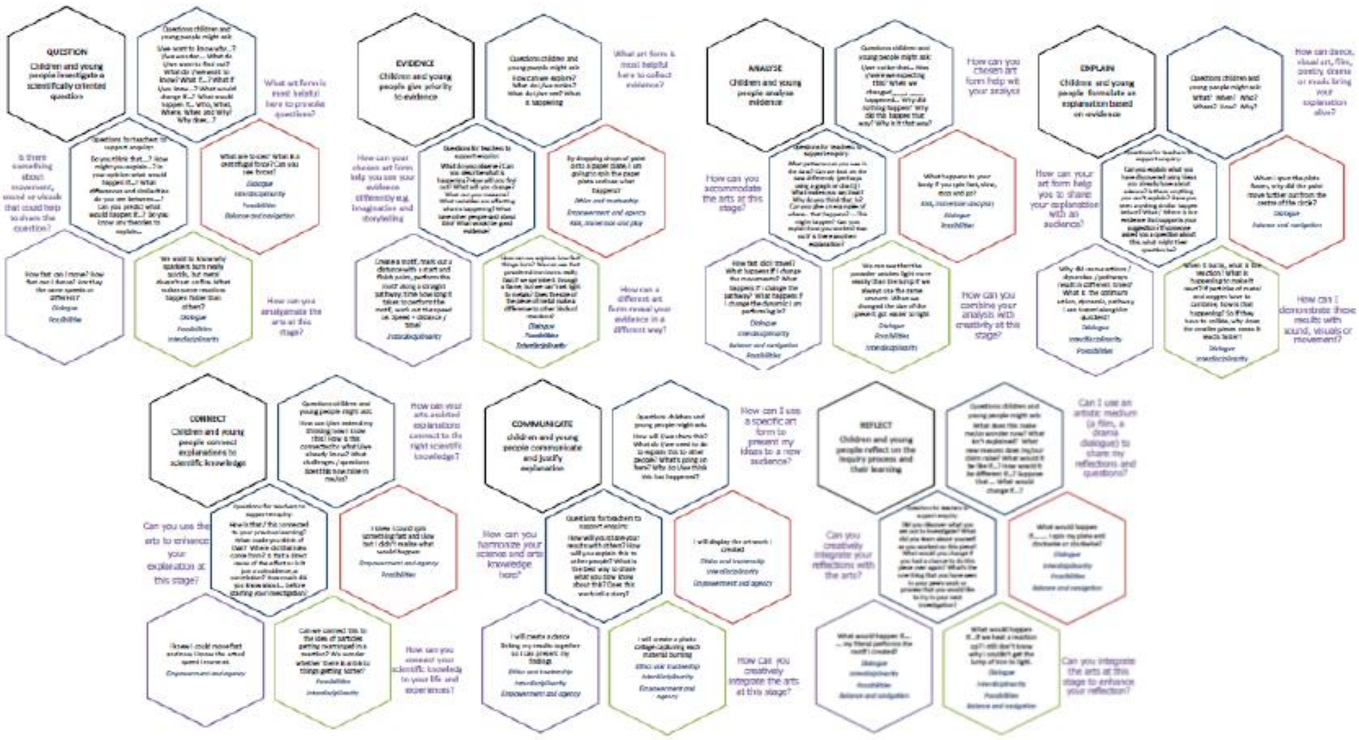

Figure 1: The honeycomb structure

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Alongside the honeycomb structure, the University of Exeter team have also developed the CREATIONS Wheel (see figure 2 below). It is expected that the teachers, scientists / researchers / artists, students and young people will engage with the CREATIONS Wheel as they generate their questions, explanations, analysis and reflections. The CREATIONS Wheel is designed to be a physical product to prompt and stimulate their thinking and creativity within the IBSE process. Throughout the process the CREATIONS Wheel will challenge 'how can the Arts/creativity be integrated at this stage in the process?'. The wheel draws on recent work within creativity in education research where a wheel structure has been used in various forms both to collect data by researchers, but also as a means for teachers and students to dialogue and ask questions about where and how creativity appears in their classroom activities. This can be tracked through the work of Spencer, Lucas and Claxton (2012), Chappell, Walsh, Kenny, Wren, Schmoelz, and Stouraitis (in review) and Slade and Chappell (2016). The CREATIONS Wheel draws on structural features of these previous wheels and the questioning and dialogue activity for teachers and students. Here the CREATIONS Wheel can be used by teachers alone or together with their students as a planning tool for embedding the CREATIONS features and arts activities into the IBSE process. Users of the Wheel are likely to begin in the central wheel which connects to the Questioning part of the IBSE process shown in the first honeycomb (the design and use of which is explained above). The Wheel and honeycombs can then be used in combination to plan an IBSE science education activity which is imbued with both the CREATIONS features and arts activities, right through to communicating findings, before they start again with Reflect/Question.

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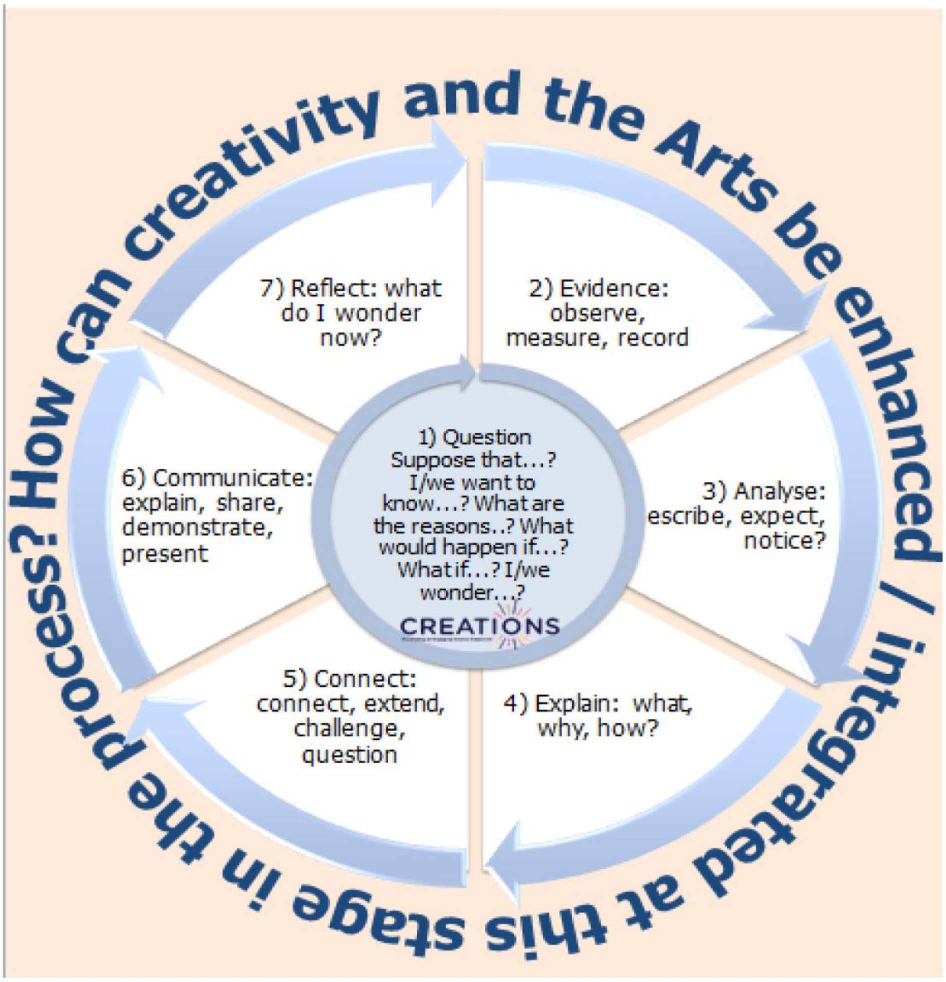
1) Starting with the **Question** stage in the centre, the young people would use the prompts to develop their own question

2) Once the question has been developed they would move through the IBSE Cycle starting with **Evidence**



3) The gaps in between the segments indicate the overarching questions, How can creativity and the Arts be enhanced / integrated at this stage in the process?

Figure 2: The CREATIONS Wheel[2]

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[2] A video demonstrating a conversation amongst young people will be made available on the CREATIONS website.

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QUESTION

Children and young people investigate a scientifically oriented question

Questions children and young people might ask:

I/we want to know why...? I/we wonder…. What do I/we want to find out? What do I/we want to know? What if...? What if I/we knew...? What would change if...? What would happen if… Who, What, Where, When and Why? Why does...?

What art form is most helpful here to provoke questions?

Is there something about movement, sound or visuals that could help to share the question?

Questions for teachers to support enquiry:

Do you think that….? How might you explain…? In your opinion what would happen if…? What differences and similarities do you see between….? Can you predict what would happen if…? Do you know any theories to explain…

What are forces? What is a centrifugal force? Can you see forces?

Dialogue

Interdisciplinarity

Possibilities

Balance and navigation

How fast can I move? How fast can I dance? Are they the same speeds or different?

Dialogue

Possibilities

We want to know why sparklers burn really quickly, but metal doesn't set on fire. What makes some reactions happen faster than others?

Dialogue

Possibilities

Interdisciplinarity

How can you amalgamate the arts at this stage?

Figure 3: Question

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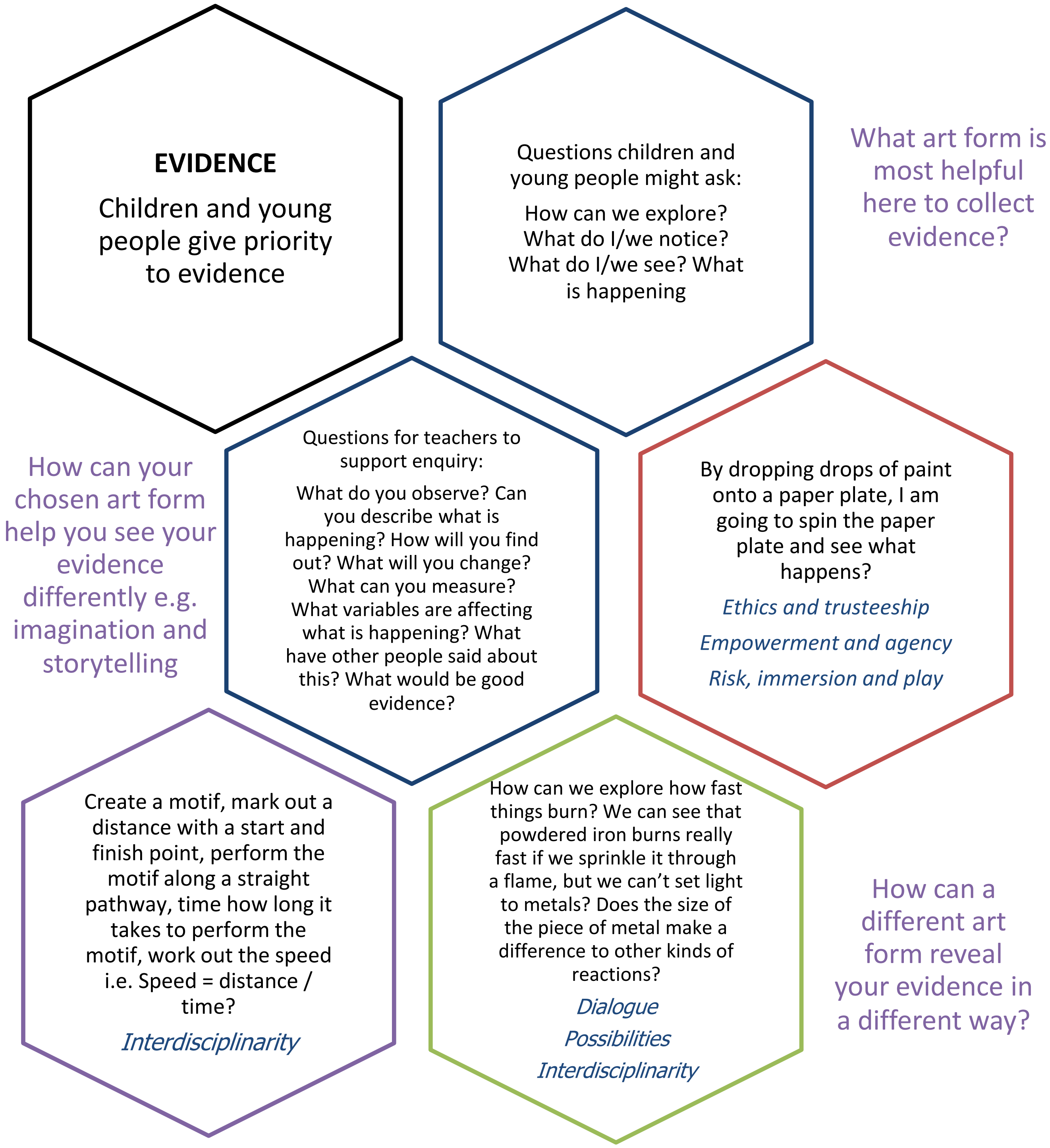

Figure 4: Evidence

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Figure 5: Analyse

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Figure 6: Explain

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Figure 7: Connect

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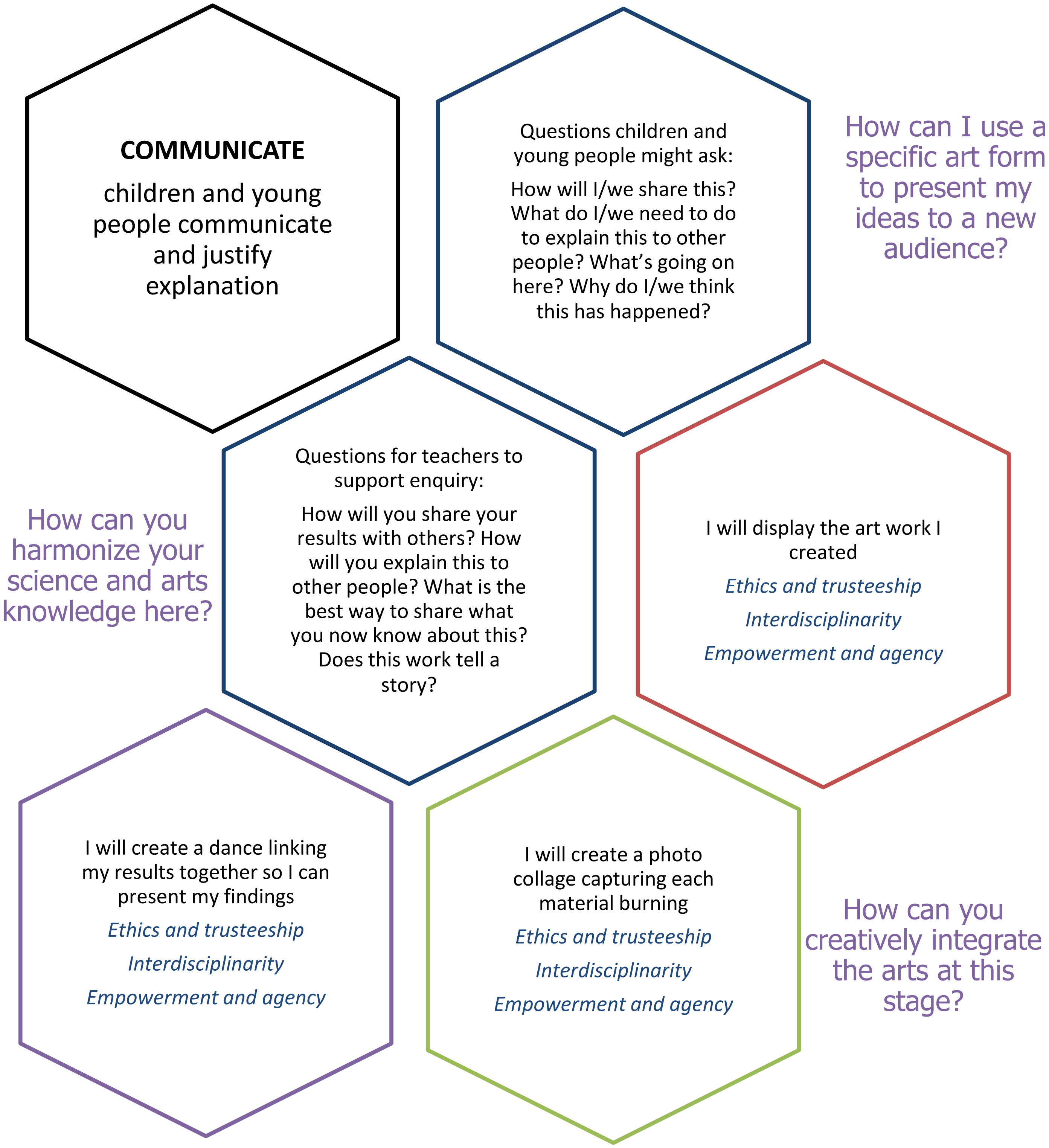

Figure 8: Communicate

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Figure 9: Reflect

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3. CREATIONS Toolkit

Below is a description of the toolkit to support the Demonstration activity in Work Package 5. This toolkit can be used by consortium staff to develop Demonstrators within their team or can be used when working with teachers, scientists / researchers / artists and students to develop their use of robust demonstrators which incorporate the CREATIONS features. Section 1 includes activities to begin introducing and engaging with the CREATIONS features. Section 2 includes activities to initiate the process of combining science questions via the Arts, IBSE and the CREATIONS features which might then lead into using the Demonstrators. During this section the CREATIONS Wheel is integrated as a tool for the participants to begin unpicking the activitives presented. Section 3 is an opportuntity for teachers, scientists / researchers / artists and students to share examples of good practice and as a group to begin identifying where the CREATIONS features are already present within their Demonstrators, pedagogy and learning. Section 4 is a self reflection task. It is expected / intended that each section would last approximately 20 – 30 minutes.

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Section 1: Introducing and unpicking the CREATIONS features

Discussion: In small groups of approximately 3 people (teachers, scientists / researchers / artists and/or students); each group is provided with a statement card (see appendix A). Participants highlight the key words and discuss / share what this might look like in their classroom context, drawing on examples where possible. This activity is particularly applicable in all three contexts (school-based activities, activities that promote school-science centre and museum collaboration and activities that promote school-research centre collaboration) where there is a need to understand how the CREATIONS features are embedded in the Demonstrators, their development and associated pedagogy.

Activity: alongside the discussion task above are some suggestions to develop a more practical activity that begins to engage with artistic activity.

- Draw, story board or cartoon strip the explanations on paper.
- Create a tableau and take a photograph with an iPad or something similar.
- Create a video demonstrating their idea recorded on an iPad or something similar.

Each group then displays their product created on the table, groups move around and interact with the presentations. As the groups visit each table and engage with the display they are allowed to leave a written comment or further question that provokes or interacts with the displayed product i.e. What questions has this provoked within themselves or their group?

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Features present in Section 1: *Dialogue, Interdisciplinarity, Individual, collaborative and communal activities for change, Possibilities, Risk, immersion and play, Ethics and trusteeship, Empowerment and agency, Balance and navigation*

Resources: Statement cards, pens, paper, technology

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Section 2: Initiate the process of combining science questions via the Arts, IBSE and the CREATIONS features.

Practical activity: Please consider the space / environment you are working in and select the appropriate activity. As you move through the activity the Facilitator will need to probe the participants gently to begin drawing out the CREATIONS features. This activity is particularly applicable in all three contexts where there is a need to connect students' curiosity and creativity with scientific knowledge, IBSE and how the CREATIONS features embed in the Demonstrators, their development and associated pedagogy.

Human Table: Set up four chairs in a square. The chairs need to be close enough that a person can lie backwards and have their shoulders rest on another chair. Four people sit in the chairs. They need to have their feet on the ground. Each person needs to lie backwards, resting their shoulders on the legs of the person behind them. One by one remove the chairs from under the bodies. The four bodies should now be a table. Replace the chairs and let them situp. (See Figure 10 and further videos on the CREATIONS website)

Alternative version: Six people stand in a circle. Can they sit on the person's lap behind them? (See Figure 11)

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1) Four Chairs in a square

2) Sitting on chairs

3) Lean back onto person's lap

4) Remove the chairs

Figure 10: Human Table

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Figure 11: Alternative Version to the Human Table[3]

After exploring the activity: Group discussions presenting how the CREATIONS features can be drawn out of the activity. This is demonstrated by taking the participants through the CREATIONS Wheel: Question, Evidence, Analyse, Explain, Connect, Communicate, Reflect.

[3] A video will be available to further explain the activity on the CREATIONS website

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Figure 12: Example of conversation using the CREATIONS Wheel[4]

Once the group has gone through the CREATIONS Wheel and identified how they could develop the above activity into a scientific exploration, begin to tease out where the CREATIONS features (from Section 1) are present; please see example below of where they might be found.

Some suggestions below:

QUESTION: Children and young people pose, select, or are given a scientifically oriented question to investigate around forces (e.g gravity, moments). *Balance and navigation* through *dialogue* aids teachers and children and young people in creatively navigating educational tensions, including between open and structured approaches to IBSE. For example: I/we want to know why we do not fall over when the chairs are removed? Questions may arise through *dialogue* between children and young peoples' scientific knowledge and knowledge inspired by *interdisciplinarity* and personal, embodied learning from aesthetic education i.e. movement, dance or gymnastics. The teacher has taken into account *ethics and trusteeship* in designing the experiment and collaborative work, as well as in the initial choice of question.

EVIDENCE: Children and young people determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as exploring the work practically, what happens if they add more people or change the shape from a square to a circle. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.

[4] A video will be available to further explain the activity on the CREATIONS website

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ANALYSE: Children and young people analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding about forces and gravity.

EXPLAIN: Children and young people use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.

CONNECT: Children and young people connect their explanations with scientific knowledge, using different ways of thinking and knowing ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.

COMMUNICATE: Communication of *possibilities*, ideas and justifications through *dialogue* with other children and young people, with science educators, and with professional scientists offer children and young people the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.

REFLECT: *Individual, collaborative and communally-based* reflective *activity for change* both consolidates learning and enables children and young people and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.

How can we engage the Arts with this activity?

Group discussion: Some suggestions - Children and young people can explore further shapes through movement i.e. counterbalance and counter tensions - they can create a dance about forces and gravity. Children and young people can engage with the Arts by

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dipping cotton wool balls in paint, and dropping them onto paper (gravity), or throwing the pompom (forces) to see what splatter shapes they make. This becomes artwork to be displayed. Children and young people can engage with film and media by making a video of themselves conducting their experiment. Children and young people can engage with music by applying different forces to a stringed instrument to compose a piece of music.

Features present in Section 2: *Dialogue, Interdisciplinarity, Individual, collaborative and communal activities for change, Possibilities, Risk, immersion and play, Ethics and trusteeship, Empowerment and agency, Balance and navigation*

Resources: Chairs, CREATIONS Wheels one per group, Video examples

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Section 3: Pedagogy, further unpicking the CREATIONS features and exploring the potential for the CREATIONS wheel.

In small groups: Participants select a science topic - biology, physics, chemistry, earth science, astronomy etc. - then an age focus, i.e. upper primary, lower secondary or upper secondary. Using the CREATIONS Wheel the groups move through each stage planning an experiment. Throughout they must identify where they can engage the Arts in the activity (see honeycombs for examples).

Allow time for the group to create a presentation explaining their activity. This can be done in any format they wish.

Present the idea to the whole group. The group then identify where the CREATIONS features might be present in the activity. The rest of the groups provide feedback: Do they see any other features present? Can they suggest any further arts activity?

Features present in Section 3: *Dialogue, Interdisciplinarity, Individual, collaborative and communal activities for change, Possibilities, Risk, immersion and play, Ethics and trusteeship, Empowerment and agency, Balance and navigation*

Resources: pens, paper, CREATIONS Wheel

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Section 4: Self reflection Connect, Extend, Challenge.

Display the three headings "Connect", "Extend", "Challenge". Each group member has three post-it notes. They complete the notes and add to the headings. After everyone has added their thoughts group reflection summarising the key themes:

- How do the CREATIONS features connect to what you already know?
- How does today's activities extend your thinking?
- What challenges do you now face to implement this?

This activity is particularly applicable in all three contexts (school-based activities, activities that promote school-science centre and museum collaboration and activities that promote school-research centre collaboration) where there is a need to understand the challenges facing embedding the CREATIONS features in the Demonstrators, their development and associated pedagogy.

Features present in Section 4: *Dialogue, Interdisciplinarity, Individual, collaborative and communal activities for change, Possibilities, Risk, immersion and play, Ethics and trusteeship, Empowerment and agency, Balance and navigation*

Resources: post-it notes

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4. Case study example: Science&Art@School

This section presents the CERN practice articulated with the IBSE processes, CREATIONS features and arts/science integration that the CREATIONS project is seeking to promote and sustain. This particular Case Study was chosen because it incorporates both school-based activities and school-research centre collaboration.

Description: Science&Art@School promotes the idea that particle physicists and artists share fertile common ground in their parallel efforts to understand physics[5]. Creating a bridge between the two disciplines is worthwhile since it can lead to a deeper understanding of each subject area. It also helps young people to think creatively and critically about the collaborative scientific effort being made at CERN, the world's largest particle physics laboratory.

Science&Art@School started as a collaboration between the CMS Communications Group and local CMS institutes, and was supported by the European Union Pathway project[6]. It takes the Arts@CMS concept a step further by bringing second-level (and sometimes third-level) students from the Arts and science curricula together with CMS scientists, science educators and art educators during extended learning periods with the aim to help students:

- understand how scientific research in high-energy physics at CMS and CERN works.
- explore how CMS researchers and artists work and view each other's world.

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- engage in and create artistic works inspired by the big physics questions driving scientific work at CMS and CERN.
- develop positive attitudes towards science and technology related work at large research infrastructures like CMS and CERN

Typical overview: Schools are invited to participate in a two-day interdisciplinary workshop Science&Art@School at their local CMS institute and/or local museum. The first day follows a typical format of a CMS Physics Masterclass7 which involves lectures, conversations, and speeches where they are presented with / introduced to a big question or theory. Students then participate in hands-on exercises concerning particle physics analysis supervised by a scientist. This is followed by a presentation of science history including a look at the close, natural links between scientists and artists over past centuries and how contemporary artists visualize modern science and technology today. The second day is dedicated to processing the previous day's input and the students are allowed space to explore the concepts using the tools and data of real life science. This culminates in the students creating a unified artwork installation of the results of their learning, in which the students, assisted by artists and art educators, progress from concept brainstorming through technical planning and practical realization to final public presentation.

Case study example: Science&Art@School Workshop | 07-09 Apr 2014, Graz, Austria

Participating schools:

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- Graz International Bilingual School (GIBS) & BORG Monsberger
- Participating CMS Institute
- Institute of High Energy Physics Vienna (HEPHY)
- Workshop co-ordinator
- Michael Hoch (CMS/CERN)
- With the support of Joanneum Universal Museum, City of Graz & Pathway Project

For the second consecutive year, Art@CMS goes to Graz, Austria, to run a Science&Art@School workshop, bringing together 55 high-school students from two high schools – Graz International Bilingual School (GIBS) & BORG Monsberger – with the aim to inspire them in the world of scientific research at CMS and CERN. Over three days, with the help of physicists from HEPHY, science educators and art teachers, the students attended lectures bridging science and the Arts, took part in a hands-on CMS masterclass, and worked on the creation of original artworks inspired by particle physics that were displayed for a day at the Joanneum Universal Museum in Graz. The workshop programme can be found here: https://drive.google.com/folderview?id=0B0N8tHZS_vu7cWdCd2pnQlRUTUE&usp=sharing

A Science&Art@School workshop is structured into three parts and typically lasts two or three days:

Day 1) Particle Physics Masterclass http://cms.web.cern.ch/content/cms-physics-masterclass

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Day 2) Creation of artworks inspired by particle physics

Day 3) Presentation of artworks and communication of learning experience throughout the workshop

As part of the first day of a Science&Art@School workshop, the students participate in a CMS Masterclass. This typically lasts up to 4 hours and includes: a presentation by a CMS scientist, hands-on experimentation with real or simulated particle physics data from the Large Hadron Collider. The Masterclass presents and poses a big question with the desire to trigger the curiosity and intrigue of the students. This generates *dialogue* for example "Anti matter: where has it gone?" "All matter is made of small particles. What is the smallest particle you know? Do you know how these particles interact with each other?" "What are the strongest forces that hold together the world?" Students then engage in *balance and navigation* with the interrelationship of what they know or suspect they know. Sometimes they are shown an example of a machine and asked "Why do we use such a big machine to study something so small?".

Triggered by these big questions in particle physics the students are then invited to search for possible answers (*Ethics and trusteeship, Empowerment and agency*). During the Masterclass, students are invited to pose questions to the CMS scientist. After the completion of the Masterclass, the students are introduced to the interconnections between science and art and are invited to question assumptions that guide scientific and artistic work. The students are then invited to think creatively about artistic concepts inspired by particle physics. This step usually takes the form of a brainstorming session (*Possibilities, Risk, immersion and play, Empowerment and agency, Balance and navigation, Dialogue*).

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Figure 13: Question posing during the Master class

The phase of hands-on experimentation with real or simulated data allows students to act as particle physicists and delve into evidence-based analysis (*Risk, immersion and play, Ethics and trusteeship, Empowerment and agency, Balance and navigation*). This phase can take the form of *individual* and *collaborative* group exercise for example "analyse the data and compare and discuss the results in a group setting". The students are *immersed* and encouraged to *play* with the data, students navigate *risk* to see if their theories are successful. The students are *empowered* as they have ownership of the data as they are in the shoes of the scientists. There is further *dialogue* opportunities as the students are able to interact with their peers, teachers, tutors and scientists.


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Figure 14: Dialogue and interaction with scientists

Under the support and guidance of a CMS scientist but also their science teacher, the students analyse real or simulated data in order to learn how to identify different tracks and distinguish between different particles that are produced by proton collisions (*Balance and navigation, Dialogue*). They also learn how to discover invisible particles, even Higgs particles. An important aspect of this activity includes collaborative learning as students typically work in pairs (*Individual, collaborative and communal activities for change, Empowerment and agency*).

In the final part of the Masterclass, the students are invited to present the results of their analysis and also to explain the analytical strategy they used to produce those results. *Empowerment and agency* are important aspects during this phase as the students start to own and feel responsible for their analysis.

Figure 15: Interdisciplinarity exploring the Arts with science

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The Masterclass exercise does not require prior knowledge of particle physics. The aim is to connect to the current curriculum the students are studying so that simple principles connect to what they have done typically the students are able to make the connection after the exercise or the practical activity. This learning is under the supervision of scientists and their science teacher so that the students can prepare and create their artwork with prearranged materials (*Possibilities, Risk, immersion and play, Ethics and trusteeship, Empowerment and agency*).

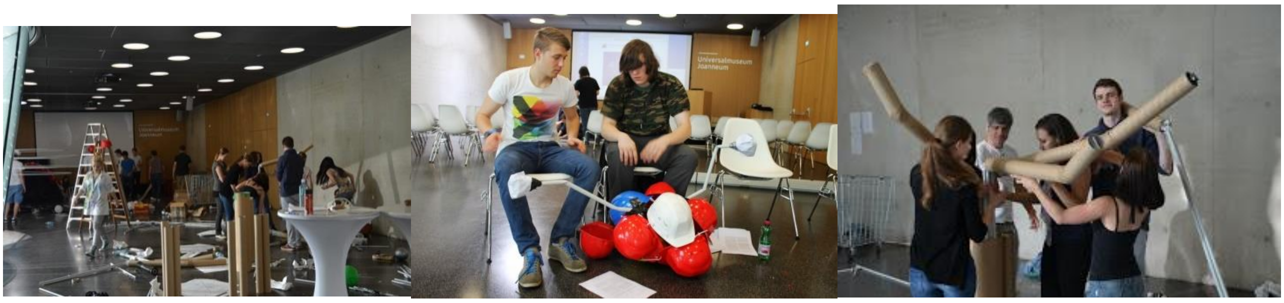

Figure 16: Developing artwork to explain their results

Students engage in *dialogue* to share the results they have created in a small exhibition. They have the opportunity (*empowerment and agency*) to share their results and present their artworks to teachers, the public, local community. This happens in a neutral space i.e. a gallery or museum. This provides them with the opportunity to engage in *individual, collaborative and communal activities* for change as they are shown how to set up gallery work as a team. Further opportunities for *empowerment and agency*, as the students are allowed to run and curate the event as they see fit. Link to the exhibit can be found here: https://www.youtube.com/watch?v=my4YC7HKUw0&feature=youtu.be

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Figure 17: Communicating their understanding

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5. Implementation support

Support is available for all consortium members developing demonstrators via the following avenues:

- Resources available on the CREATIONS website: INSERT WEBLINK
- Resources include: Power Point presentation of the suggested activities, video examples of students and young people engaging with the CREATIONS Wheel, video examples of teachers performing the practical activities
- The University of Exeter (UoE) team will lead consortium members through a selection of the activities at the CREATIONS Project Meeting in Athens, Greece in May 2016.
- The UoE team is available after this workshop for on-going support and discussion with the Partners via Skype and email. On behalf of the UoE team, Charlotte Slade (c.slade2@exeter.ac.uk) will contact key people in each consortium member to ensure that they are secure in embedding CREATIONS features in demonstrators. This will need monitoring but consortium members may also wish to adapt the toolkit in order to embed it within their own demonstrators for teachers/scientists/artists to use.

As consortium members work on CREATIONs demonstrators, it is therefore anticipated that they will reflect on how well CREATIONs features are embedded into them. This process may be as simple as a brief check-list approach which can be seen in the example below from the UK, where the team have checked that each CREATIONs feature is present within the spread of their implementation activities. Equally, it may be a more complex and detailed reflection such as the CERN case study example above, where the CREATIONs features are mapped into a detailed

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description of the CERN demonstrators. The level at which these reflections take place is dependent on the interest, resource etc of each consortium member.

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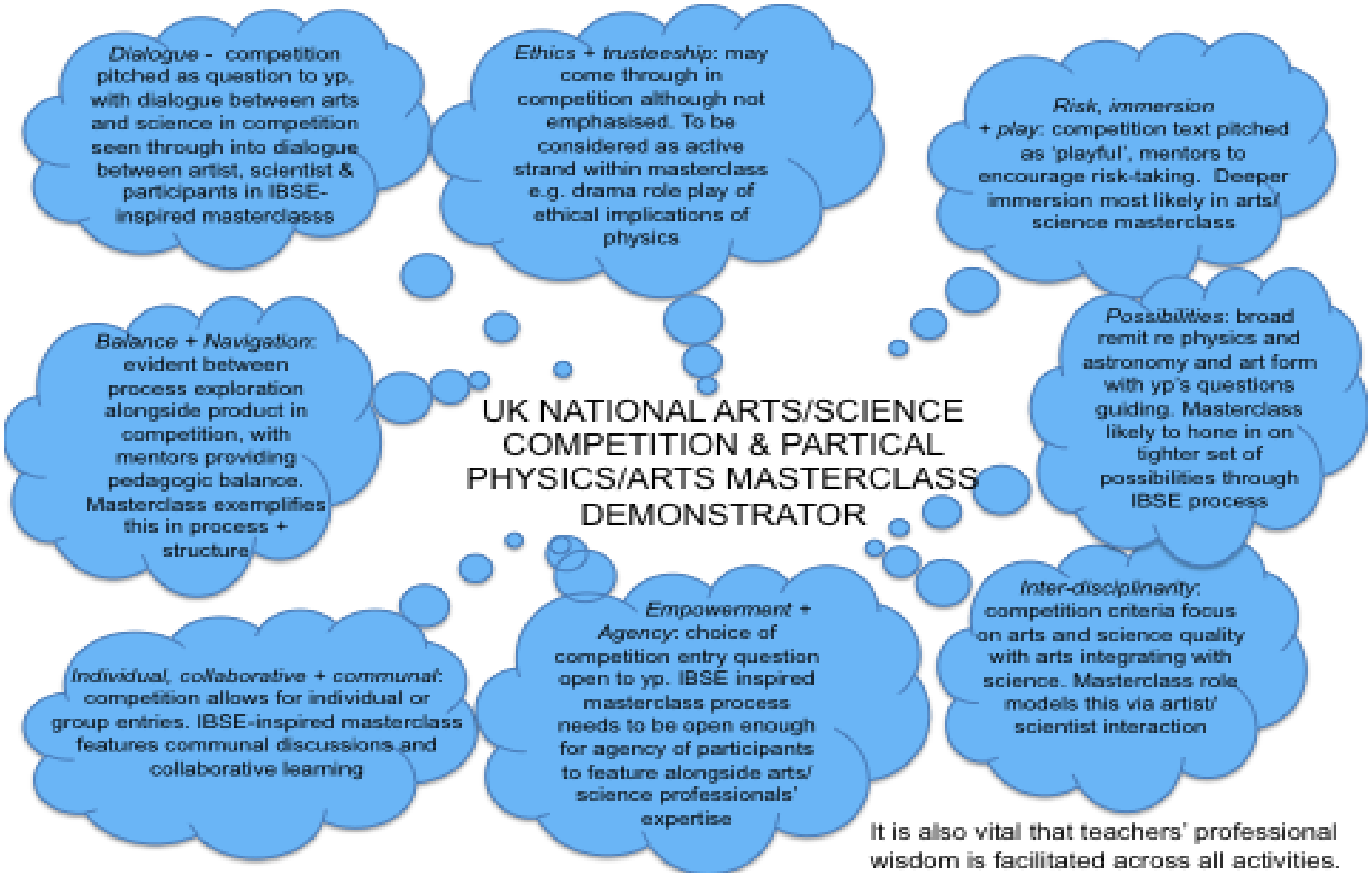

It is also vital that teachers' professional wisdom is facilitated across all activities.

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6. References

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7. Appendix Resources

A) Statement cards

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Appendix A Statement Cards

Cut up each paragraph to make the statement card

***Dialogue**:* Practice can allow for dialogues (questions leading to answers leading to questions...) between people, disciplines (arts and sciences), creativity and identity (as scientist, artist, teacher, learner), and ideas. This dialogue needs to acknowledge embodiment (i.e. dialogue can also be a physical activity especially within the performing arts) and differences of opinion. It also needs to allow for conflict within the questioning process. It is important to facilitate open discussions of the questions generated by students and bring these into conversation with current relevant questions from professional scientists and science educators.

What does this look like in the science classroom? How can we engage the Arts with this feature?

Interdisciplinarity: This is grounded in the *interrelationship of different ways of thinking and knowing* which means allowing space for different ways of thinking (e.g. problem-finding, exploring, reasoning, reflecting, questioning, experimenting) around shared arts/science questions. At the Arts/science interface there are also three different ways of knowing (knowing that - propositional knowledge e.g. I know that is a bunsen burner, knowing how - practical knowledge e.g. I know how to conduct this experiment, knowing this - aesthetic or felt knowledge e.g. I know how to decide that my dance choreography works through assesing how it feels), as well as acknowledging the embodied/physical alongside the verbal. Within interdisciplinarity it is vital to respect rigorous science and art *discipline knowledge*, as well as understanding the importance of discipline-relevant materials (e.g. bodies, props, paper and pencil, sculpting materials, Bunsen burners and

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test tubes, chemicals, equations) and how creativity might interact with these disciplinary knowledges differently, albeit in the context of science education.

What does this look like in the science classroom? How can we engage the Arts with this feature?

Individual, collaborative and communal activities for change: Practice can allow adult professionals and students to engage at all three levels. This is particularly the case regarding communal engagement where students and adults can take advantage of group identities within which participants will work (e.g. within a performance group to share science findings or a science team to conduct an experiment), allowing for difference but with a shared creative process and purpose. Employing available tools such as digital technology (e.g. social media, online resources and sharing facilities and novel science-focused technologies) to support this process, can also build on what is possible creatively in a face to face situation in the classroom.

What does this look like in the science classroom? How can we engage the Arts with this feature?

Balance and navigation: Practice can generate creativity in education by balancing control and freedom, structure and openness, stepping back and stepping in, and prior knowledge and new knowledge. Practice can also acknowledge the common educational tensions and dilemmas of accountability/assessment, marketisation and resource/time pressures. Rather than allowing performativity to take over from creativity through overt teaching to the test, the aim is for practice to *navigate* these tensions with creativity in order to achieve results but doing so in a creative way.

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What does this look like in the science classroom? How can we engage the Arts with this feature?

Empowerment and agency: Empowering pedagogies can allow both learners and adult professionals to gain a greater sense of their own agency and ability to express themselves, and to then know what to do with that in order to be more creative scientists and to develop more creative science teaching techniques. This means enabling pupil agency and encouraging children to try out (and critique) their own ideas and questions in investigations.

What does this look like in the science classroom?, how can we engage the Arts with this feature?

Risk, immersion and play: allowing for these three processes to happen across teaching/facilitation and learning and recognizing how pedagogy can assist in creating literal space as well as 'thinking' space for these to occur. This can be achieved by creating a trusting space in which mistakes are possible and there is no fear of failure.

What does this look like in the science classroom, how can we engage the Arts with this feature?

Possibilities: practice can allow for multiple possibilities both in terms of thinking and spaces (e.g. using spaces differently within classrooms as well as taking advantage of digital spaces). This also means adult professionals knowing when it is appropriate to narrow or broaden these spaces in the context of asking 'what if' questions

What does this look like in the science classroom, how can we engage the Arts with this feature?

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Ethics and trusteeship: adult professionals and learners consider the ethics of their creative science processes and products and are guided in their decision-making by what matters to them as a community, acting as 'trustees' of that decision-making and its outcomes.

What does this look like in the science classroom, how can we engage the Arts with this feature?

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