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Development of STEM Outreach Material that Incorporates Argumentation for Science Classrooms

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Abstract

The main goal of this project is to merge best practice in STEM outreach/informal/non-formal education and argumentation research to create an effective programme for teachers and outreach practitioners. This is due the fact that many outreach activities to date have limitations that prevent successful development and implementation from both parties [1;2]. The majority of STEM education research is carried out within the formal learning environment. The OECD [3] describe formal learning as an intentional, organised event, with learning objectives. This project is a shift away from curriculum-based education, however, that is not to say that the educational experience cannot be linked to the curriculum. The rationale for using argumentation is largely due to the fact it is recognised as one of the four key areas required to improve scientific literacy. The use of argumentation practices in education can help improve critical thinking, higher order processes and public reasoning on top of numerous other skills [4]. Thus, developing the use of argumentation in STEM outreach programmes should help foster more expansive and joint pedagogical approaches by teachers and outreach practioners alike. This paper will focus on the development and trial of an outreach lesson that will incorporate argumentation techniques [5]. This study took place in Irish classrooms and utilised information from both in-service Science teachers and STEM outreach providers.

Keywords: *STEM Outreach, Argumentation, Science Outreach, discourse.*

Introduction:

Science Outreach in Education:

Outreach programmes are unique in the fact they can take place in formal environments, while also taking place in non-formal and informal settings, depending on the goal of the programme [6].Although formal schooling is the main provider of educational experiences, the informal education sector can be a critical element of STEM education [7]. This places emphasis on the importance of creating mutually beneficial material for outreach practitioners and the formal education community. The main aim of science outreach and engagement is to "increase the size and diversity of the science workforce" [2, p49]. It is an essential part of building scientific literacy and a crucial way to keep future scientists interested in a subject. The overall intention of outreach is assisting in the important growth of social and economic development in Ireland [8; 9]. Walker [10] has described science outreach as a way of improving the recruitment and retention of pupils, while also recognising its importance for promoting the vulnerable physical science subjects. Universities and additional organizations have realised the impact outreach can have on Primary and Post-Primary pupils through improving pupil engagement and acting as a direct support for education in the classroom [11].

Table 1. Key contributors in STEM outreach in Ireland [adapted from 12]

Contributor	Key Characteristics
STEM Outreach Practitioner	• Motivate pupils • New learning experience • Select content • Engage • CPD for Teachers
School Staff Member/ Teacher	• Select suitable content • Select suitable activities for classroom • Select pupils • Select time frame

Pupils	• Participate • Engagement • Motivation towards STEM

Outreach involves many different stakeholders (Table 1), all of whom have similar, yet different aims in relation to areas of study, overall goals and funding opportunities. Many science outreach providers are looking to expose pupils to areas that they may not have experienced at school [13].

What is Argumentation:

Argumentation is an instructional approach, and an educational goal for science education [14]. It utilises evidence-based justification of knowledge and claims and supports reasoning across all STEM domains [15]. It can be described as a discourse through which arguments are constructed and evaluated using evidence, justifications, and rebuttals [15]. An effective science education programme enables a pupil to apply their knowledge and understandings of science in real-life situations based on public issues [16]

Argumentation is considered as a key pillar of developing scientific literacy, due to the fact it entices pupils to develop their critical thinking and communication skills [15; 4]. In recent times, argumentation has become an important process in science education practices in Ireland. It has been included in the new Junior Cycle curriculum, as one of the eight key skills being promoted to improve student's literacy. The key skill involves being able to "plan, draft and present scientific arguments, express opinions supported by evidence, and explain and describe scientific phenomena and relationships." [17, p8].

The importance of incorporating argument, critical reasoning and nature of science has been highlighted by the research [5]. Concentrating on incorporating argumentation practices into science education allows students experience science as it is [5]. Scientists are aware that arguments are key elements in the process of convincing the scientific community about their findings [18], however, it often gets lost in science education [16]. It is recognised that argumentation has significant relevance on the development of our future citizens, as everyone must make personal and ethical decisions about a range of socio-scientific issues at some stage [19]. This leaves an opening for a framework to be developed and utilised.

Science outreach has a long history of working with schools to improve both, participation in science and scientific literacy [8]. As argumentation contributes to the development of the student, there is an opening for this pedagogy to be used effectively in the development of material. This research will aim to bridge the gap between informal/non-formal and formal learning through developing a defined pedagogical approach aimed at meeting the goals of both sectors.

Methodology:

The initial information that guided this research involved outreach providers participating in a baseline questionnaire. they were selected using information from a previous study in Ireland [8], in addition to an in-depth search of new and recently formed research centres and outreach providers was carried out by the researcher. A sample size of ~60 STEM Outreach Providers in Ireland were contacted by an email which contained the details of the study, and the requirements involved for participation.

Once the questionnaire was completed and analysed both outreach providers and teachers were contacted to take part in the semi-structured interviews. An email was used to recruit the participants. In total, there was ten participants five teachers and five outreach providers. The outreach participants were selected at random from this pool of people who took part in the questionnaire. There were five participants, one male and four females. The participants were located across different regions of Ireland including the South-East and the South-West of Ireland. The teachers had previously been in contact with the researcher and came from a variety of schools including vocational, community college and voluntary. One male and four female teachers took part in the project with varying levels of experience.

Development of Activity:

The outreach providers questionnaire provided some key insights to Questionnaires were sent to 59 outreach providers, and 30 (51%) replies were obtained. In terms of developing material, each outreach provider is going to have their own desired goals. These goals will be dependent on their funding bodies, area of interest and the target group of the project. However, one of the questions to

the outreach providers was about the provision of guidelines when developing the material. This yielded some interesting results as 63% (n=19) of the participants stated they have guidelines to follow, while the other 37% (n=11) did not have guidelines to comply with. This allowed for the activity to be open when in development.

On top of the questionnaires both outreach providers and teachers were interviewed. The interviews outlined certain themes that had to be dealt with which are outlined below in table 2.

Table 2. Key themes from interviews.

Key challenges Identified in Cycle 1	**Design Solutions Implemented for Design of resource:**
Teacher self-efficacy	A teacher information sheet was placed at the beginning of each lesson to give them an insight in to the area and allow them to improve their knowledge.
Teacher Questioning	Have both lower and higher order questions for the teachers. This will allow them facilitate the class.
Real-life contextualised science	Each lesson related to research currently taking place In Ireland.
Curriculum and time constraints	Related all lessons to the new Junior Cycle Learning Outcomes/ Transition Year. Or Leaving Certificate curriculum.
Lack of goals	Clear outline of what is happening and what the pupils will know at the end of the activity. Learning objectives clearly defined.

With these themes in mind 6 topics were chosen based on Irish research, each lesson was developed under many different headings including and outline of the lesson, key questions, type of argumentation activity and a student hand out. Table 3 below shows an example of how we linked all the information together.

Table 3. Sample Activity.

TITLE	**Outreach Topic**	**Brief Outline:**	**Irish Research Link**	**Argumentation Activity**
Spot the difference	Graphs and spectrometry	Discussing how variances in graphs and results can differ.	Spectroscopy in a Suitcase (SIAS) – numerous outreach visits per year.	A common point of argument for scientists is when data are inconclusive and can support two or more views about their interpretation. How does one resolve the situation where there are many varying measurements of the same phenomenon

Future Work:

Data analysis is currently being carried out all information gathered from the lesson implementation.This will inform the next phase of the project.

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