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Investigating the effect of scientist demonstrators on primary children's science self-efficacy

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Abstract

Emergent in the literature is the need to increase levels of student engagement in science, with informal science education (ISE) playing a fundamental role. Whilst children find science to be interesting and important to society, children can view science as difficult and not 'for them', which can be interpreted as having low Science Self-Efficacy (SSE). SSE is the self-belief an individual has in their own abilities to perform scientific tasks successfully in a given context. There is currently limited extant SSE research focusing on primary school children. Furthermore, children's SSE has not yet been explored in the Irish context, nor has the influence of scientists on SSE been investigated. Due to the recent rise in ISE initiatives aiming to increase children's science aspirations, it is necessary to inform providers of informal science education of best practices regarding their influence on children's SSE. This work describes the design and validation of a novel questionnaire developed to measure 10 to 13 years old children's SSE beliefs and their sources in the Irish primary school context, including a measurement of perceived scientist demonstrator credibility and competence.

Keywords**:** *science self-efficacy, informal science education, primary science education*

1. Introduction

1.1. Children's science self-efficacy and informal science education

Many ISE initiatives aim to improve uptake in science subjects by increasing children's interest and enjoyment [1]. This, in addition to increasing demands from funding agencies for scientists to participate in public engagement, has resulted in a recent increase in ISE activities facilitated by scientists in Ireland [1].

However, although standardised test scores such as PISA, and various research studies show that Irish children perform well in science, and find it interesting and enjoyable [2]-[3], the level of scientist graduates in Ireland has remained at 28% since 2015 [2]. Therefore, a child's interest or academic ability in science does not necessarily translate to motivation or aspiration.

The ASPIRES study has illustrated that many children do not aspire to be scientists as they perceive it to be too difficult and not 'for them' [4]. This lack of belief in one's abilities can be referred to as having low self-efficacy. Those with low self-efficacy withdraw from tasks they perceive to be too difficult [5]. Self-efficacy can be described as the belief an individual has in their own abilities to perform successfully at specific tasks in given contexts [5]. This suggests that scientists in ISE initiatives could better address the issue of student motivation and aspiration by aiming to increase student's science self-efficacy.

1.2. Measuring science self-efficacy

Self-efficacy theory describes four major sources: 1) Mastery experiences: experiences of an individual successfully performing a specific task, 2) Emotional state: the mood an individual experiences whilst conducting a specific task, 3) Vicarious experience: observing others performing specific tasks, and 4) Social persuasion: others expressing belief in an individual's capabilities [5].

The literature reveals some research exploring the influence of these four sources on children's SSE across different formal learning contexts, including mathematics and science [6-8]. Existing research investigating ISE activities is sparse, focusing on long-term after-school programmes, camps or museums [9]. Whilst research exists examining the influence of parents, friends and teachers as sources of SSE, no research has yet investigated scientists as sources of SSE [5,7]. Thus, research on SSE in conjunction with short-term ISE initiatives led by scientists at primary level is warranted.

In order to investigate the potential influence scientists in ISE activities have on children's SSE in Ireland, a suitable measurement instrument is needed. To measure self-efficacy strengths and

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sources, researchers often use scales within self-completed questionnaires [5-6,8,10]. Participants use these scales to self-rate their perceived confidence in different tasks and subjects [7].

The work presented here describes the modification of existing SSE scales in order to generate scales to measure Irish primary school children's SSE and related sources pre- and post-participation in a scientist-led science outreach activity.

2. Questionnaire design

The questionnaire was designed by drawing on existing self-efficacy scales from science and mathematics [6,11]. To suit the research context, items were modified to align with the Irish primary science curriculum learning outcomes [12]. Bandura's '*Guide to constructing self-efficacy scales'* was used to inform modifications and changes [10].
The structure and content of the resulting science self-efficacy questionnaire *(*SSE questionnaire), containing 6 subscales, is outlined in Table 1.
The 'Sources of SSE' subscale is further divided into items that measure each of the four sources (mastery experience, vicarious experience, social persuasion and emotional state). The 'Perceived scientist credibility and competence' subscale, adapted from Gray et al. [13], is subdivided into negative and positive statements.

Table 1. Science self-efficacy questionnaire subscales, number of items in each, examples, scale descriptors and original sources of items. SS=self-efficacy, SSE=science self-efficacy

Subscale	Further divisions	No. Items	Example of questions and *statements*	Scale Descriptors	Original Source
General Academic SE		4	How well can you '*learn about Science*?'	1=Terribly 7=Perfectly	Taken from [10]
Performance-related SSE		3	How confident are you that could '*get a 5'* out of 5 in science in the next report card?	1=Extremely doubtful 7=Extremely confident	Adapted from [8]
Domain-Specific SSE		10	How well could you answer questions on *'Insects & minibeasts?'*	1=Terribly 7=Perfectly	Styled on [8], items based on [12]
Task-Specific SSE		7	How well could you *'Come up with an idea to be tested?'*	1=Terribly 7=Perfectly	Styled on [8], items based on [12]
Sources of SSE	-*Mastery experience*	2	How much do you agree with '*I have always been very successful with science'?*	1=Strongly disagree 7=Strongly agree	Adapted from [6]
	-*Vicarious experience*	4	How much do you agree with *'Seeing adults do well in science pushes me to do better'?*	1=Strongly disagree 7=Strongly agree	Adapted from [6]
	-*Social persuasion*	3	How much do you agree with *'Adults have told me that I am good at science?'*	1=Strongly disagree 7=Strongly agree	Adapted from [6]
	-*Emotional state*	1	How much do you agree with '*Just being in science class makes me happy?'*	1=Strongly disagree 7=Strongly agree	Adapted from [6]
Perceived scientist credibility and competence	-*Negative statements*	2	How much do you agree with *'My scientist demonstrator was not friendly?'*	1=Strongly disagree 7=Strongly agree	Adapted from [13]
	-*Positive statements*	3	How much do you agree with *'My scientist demonstrator was well trained in science?'*	1=Strongly disagree 7=Strongly agree	Adapted from [13]

Participants rate their answers using a 7-point Likert scale as a compromise between using recommended larger scales [10] and the smaller 5 point scale normally used with young children. This strategy was employed in a similar study in England [8]. Descriptors were added at each point of the scale in an attempt to improve scale interpretation (see Figure 1 for example of scale descriptors), as recommended by Bell et al. [14].

Figure 1. The 7-point Likert-like scale used in the SSE questionnaire

The questionnaire was reviewed by two educational researchers, two experienced 6th class teachers, one informal science educator facilitator and two social researchers.

3. Pilot study

3.1. Participant details and method

Eight-three children aged between 10 and 13 years from three different Irish Primary schools (all 6th class) completed the novel SSE questionnaire before (24 hours in advance) and directly after participation in the *Fantastic DNA* session delivered by a team of five Cell EXPLORERS scientists. Cell EXPLORERS is a university-led outreach programme which features scientist demonstrators as activity facilitators. In this activity, children are introduced to DNA and genetics and are guided by scientist demonstrators to individually extract DNA from a banana.

Two boys (12 and 13 years) and two girls (both 12 years) were randomly selected from one participating school for one-on-one interviews approximately two weeks after participation. Children were interviewed about the choices they made on both questionnaires.

Children's science self-efficacy questionnaire answers were input directly into the statistical programme SPSS. Interviews were transcribed and coded using content analysis. Analysis of the post-questionnaire and interviews are discussed below.

4. Results & discussion

4.1. Most subscales show good homogeneity

Principle component analysis was used to determine the homogeneity of items within the proposed subscales. Most of the subscales illustrated good homogeneity: the items within the subscales were well correlated with each other. However, the homogeneity of the domain-specific SSE subscale could be further improved with the removal of one item concerning 'magnets' (alpha coefficient of subscale with item: .706, without: .715). To improve this subscale, 'magnets' will be added to another item dealing with 'bulbs, batteries and switches', instead of removing an important part of the Irish primary science curriculum, a strategy employed by another study [8].

4.2. Children understood the 7-point Likert-scale

Answers from the small sample of interviews indicate that children understood how to interpret the scale. For example, students chose answer 4 ("neither poorly or well" or "neither agree nor disagree") on the scale when they considered themselves to be average, as opposed to choosing a non-answer.

Interviewer: "…*so here for magnets you picked neither poorly nor well, do you want to talk to me a little about that?"*

'Eddie'*: "Em I don't really get how it works that much but I don't find it extremely hard either"*

'Eddie', Male, 13 years old

4.3. Children misinterpreted the performance-based subscale

This subscale, asking children to report their confidence in achieving a certain grade in science in their next home report, was at risk at being misinterpreted as Irish children are not formally tested in science. If interpreted correctly, the mean SSE scores should be increasing from 'Get a 5' to 'Get a 3',

as those who are confident in achieving a 5, should be even more confident they will achieve a 3. However, as the descriptive statistics outlined in table 2 reveal, this was not the case. Children interpreted this subscale as a measure of likelihood of them achieving a certain grade, not their confidence.

'Kate': *"here we got really confused about that 'cause everyone was like, wait 'cause we like the questions on this one, em, I'd be very doubtful I'd get a 3 but I know I'd get higher so everyone got confused"*

'Kate', Female. 12 years old

Thus, it was not the concept of grading themselves in science that confused children, but the wording of the question. To avoid this, this section will be reworded to ask children: 'How confident are you that you would get at least the following out of 5 in science in a home report?'

Table 2. Mean scores on the performance-based SSE items in the SSE questionnaire

Performance related SSE item	Mean	Std. Deviation
Get a 5	4.59	1.105
Get a 4	5.06	1.058
Get a 3	4.88	1.574

4.4. Reliability of subscales

An important aim of the pilot was to investigate the reliability and validity of the subscales as measures of each self-efficacy construct. The Cronbach's alpha for each subscale was calculated to determine their internal consistency reliabilities [10]. Table 3 outlines the Cronbach's alpha coefficients for each of the subscales in the post SSE questionnaire.

Table 3. Cronbach alpha coefficients for subscales from the post Science Self-Efficacy Questionnaire. *=low alpha coefficients

Subscale	Post questionnaire α
General Academic SE	.60
Performance-related SSE	.37*
Domain-specific SSE	.81
Task-specific SSE	.79
Sources of SSE	.90
-Mastery experience	.78
-Vicarious experience	.88
-Social persuasions	.89
-Emotional state	-
Perceived scientist credibility and competence	.14*
-Negative statements	.55*
-Positive statements	.71

The subscales yielded moderate to high alpha coefficients (between 0.60-0.90) with two exceptions. The low coefficient for performance-related SSE can be attributed to the confusion children encountered interpreting this subscale. Changing the wording of the instructions as described in 4.2. should improve this. The low coefficient for 'Perceived scientist credibility and competence' is low (α=.14) due to the presence of positive (e.g. *My scientist demonstrator was clever)* and negative statements (e.g. *My scientist demonstrator encouraged me in the activities)*. When considered separately, their alpha coefficients were sufficiently improved.

This preliminary analysis reveals that the adaptions made to existing SSE scales to suit the Irish primary school context were successful overall, and can be improved with minor modifications. These will be tested in a second pilot. Then, the main phase of this study will start to investigate strengths and sources of children's SSE following participation in a scientist-led outreach activity.

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