Story of a Seed: educational theatre improves students’ comprehension of plant reproduction and attitudes to plants in primary science education

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ABSTRACT

Background: Although plant reproduction is a core subject in school science curricula, botanical topics are typically unpopular with students. Integrating the arts into science subject matter has the potential to increase student interest and understanding. Educational theatre has shown particular promise in this area.

Purpose: The study examined how an interactive theatre performance, where professional actors deliver a performance but invite regular audience participation as a way to promote active learning, benefited both understanding of plant reproduction and attitudes towards plants. Perceptions of the play and the way in which specific elements influenced learning and emotions were examined in detail and placed in a theoretical context.

Sample: Opportunity sampling was used to recruit participants from five public primary schools in Devon, UK. One hundred and forty-four students (aged 9–11 years) participated in the study.

Design and methods: A mixed methods approach was adopted. Quantitative analysis of pre- and post-intervention knowledge tests involved t-tests and repeated measures ANCOVA. Qualitative analysis of semi-structured interviews made use of an emerging theme analysis with a priori categories.

Results: Pre- and post-intervention tests indicated an increase in both knowledge of plant reproduction and positive attitudes towards plants. Follow-up interviews identified elements that were particularly beneficial for learning and enjoyment, including the thematic singing, humour, novelty of the play, visual elements and participatory art activities.

Conclusions: This case study demonstrates the potential that an interactive theatre production offers for enhancing appreciation and interest in school science while improving knowledge.

Introduction

Children enjoy science at primary school level but interest in science diminishes between the ages of 10 and 14 years (Archer et al. 2010; DeWitt et al. 2013). Aspirations to be scientists
are low in children and young people of all ages, particularly girls. Poor scientific literacy among primary school teachers can result in attitudes towards science that contribute to the problem (Van Aalderen-Smeets and Walma van der Molen 2015). Innovative teaching methods are needed to sustain students’ interest in science and make it more attractive as a career choice. The integration of the arts into science education promoted by the STEAM movement has received growing attention for its potential to increase school students’ interest in science as well as to foster creative thinking and practice in STEM disciplines (Sousa and Pilecki 2013). Incorporating art and design, drama and musical composition into the science classroom has been shown to enhance learning and enjoyment (Lerman 2005; Crowther 2012; Hardiman, Rinne, and Yarmolinskaya 2014; Çil 2015).

The use of the dramatic arts as a pedagogical tool is not a new idea. A prominent example of its use in the UK is the Theatre in Education (TIE) movement, initiated by professional theatrical groups in the 1960s (Jackson 2002). TIE and other contemporary theatrical initiatives have placed the emphasis not just on subject-specific concepts but on cultivating creativity and enthusiasm, appreciating the nature of science and learning about science’s interactions with society (Ødegåard 2003).

In reviewing a number of drama in science projects, Ødegåard (2003) concluded that educational benefits were mainly in the realm of higher level cognitive (e.g. comprehension, interpretation) and affective skills (e.g. attitudes, confidence, empathy) rather than factual recall. Similarly, Metcalfe et al. (1984) found that the use of drama in chemistry lessons did not increase factual recall but did improve students’ ability to explain and apply concepts. Jansson and Aksela (2013) noted that theatrical audiences were impressed less by the science itself and more about the persona and life of the scientist, and by extension the place of science in society. Dorion’s (2009) examination of drama use in science classrooms looked at its ability to alter perspectives and promote dialogue and positive affect.

Other studies, however, have shown more direct benefits on learning. Bailey and Watson (1998) found that a drama/role-play exercise improved students’ knowledge on a range of ecological concepts. Peleg and Baram-Tsabari (2011) reported that watching a play on the subject of physical chemistry had positive effects not only on affect but on factual knowledge. Students participating in a drama activity about the electrolysis of water exhibited higher knowledge gains than students engaged in a non-drama activity (Saricayır 2010). Drama-based instruction about the states of matter and methods of heat transfer increased knowledge and positive attitudes towards science to a greater extent than a non-drama control group (Abed 2016).

The play produced for the present study, Story of a Seed, adopted the medium of interactive theatre where professional actors deliver a performance but invite regular audience participation as a way to promote active learning (Peleg and Baram-Tsabari 2011). The aim of the play was to communicate plant reproduction to children aged 9–11 years. The play was not designed to replace formal classroom instruction but to provide an introduction to the topic, as a way of stimulating student interest and learning. Given previous mixed findings, we were particularly interested in whether the experience would lead to retained knowledge beyond the initial experience.

Plant reproduction is a topic included in primary and secondary curricula in most countries (Schussler and Olzak 2008). In the UK, children are introduced to this topic at the age of 10–11 years (Government Digital Service 2016). Children are required to learn to label the reproductive organs in a diagram of a flower and develop a conceptual understanding of
pollination (transfer of pollen to female reproductive organs), fertilisation (fusion of male and female reproductive cells) and seed dispersal (movement or transport of seeds away from the parent plant). In primary schools, pedagogical methods include the dissection and drawing of a flower, investigating work about plant life cycles and a variety of educational games (Link-Pérez and Schussler 2013; Science and Plants for Schools 2016).

The low interest children have in plants is attributed to the phenomenon of 'plant blindness'; an inability to notice or value plants in the environment (Schussler and Olzak 2008; Link-Pérez and Schussler 2013). Educational media present plants in a less charismatic light than animals, and instructional methods may fail to foster an interest in plants. Children develop at best a partial understanding of plant reproduction through school science and exhibit misconceptions about the topic. For these reasons, plant reproduction is an ideal subject for piloting a novel engagement activity.

The research questions for the study: (1) How does an interactive theatre performance about plant reproduction influence children's knowledge and attitudes towards plant science? (2) What are children's perceptions of the play and how do specific elements of the play influence learning and emotions?

Theoretical framework

We position theatre as a pedagogical tool that promotes the aims of humanistic science education as proposed by Yoon (2006) and Peleg and Baram-Tsabari (2011) in their studies on educational science theatre. Humanistic perspectives in science have existed for more than 150 years. Their importance in science education is well articulated by Aikenhead (1996, 2006, 2007) and Lemke (2001), who draw attention to the fact that science education is about learning to navigate the culture of science as well as knowledge acquisition, and that culture is often at odds with the subcultures that students occupy outside of school science. To become more accessible, school science needs to share some of the social and cultural characteristics of students' everyday worlds. We suggest that theatre has the power to render school science more accessible through its use of narrative and metaphor, and emotional engagement.

Narrative and metaphor

Theatre is based on a narrative or story, a naturalistic account of connected events (Ødegaard 2003). Narrative does feature in science education but the dominant mode is argumentation: reasoning in support of an idea or theory, the use of formal or empirical evidence (Aikenhead 2006). Whilst argumentation is an essential aspect of learning science, stories may be particularly valuable for making science more accessible. Drama also invites the observer to enter into the story and experience it more fully (Wong and Pugh 2001). The value of stories is their ability to weave together disparate concepts and tap into familiar experiences and themes, making the science topic more meaningful and comprehensible (Millar and Osborne 1998; Negrete and Lartigue 2004). Graesser et al. (1980) proved that narrative prose generated superior recall compared to expository prose, for a sample of college students. Thorndyke (1977) elaborated how the structure of a plot in a narrative determines the depth of comprehension and subsequent recall. Comprehension is required for encoding of information and formation of schema, the memory structures formed in the brain.

A good story is evocative; it enhances the affective qualities of its subject matter, which can increase enjoyment. The evocative nature of theatre is enhanced through its use of
metaphor, where music, characters, movement or objects are used to embody abstracts ideas or concepts (Ødegaard 2003; Winston 2008). The use of imagery produces particularly rich and accessible memories, especially if concepts are presented simultaneously in verbal and visual modes (Clark and Paivio 1991). Mayer (2005) argues that having to integrate information from multiple modalities leads to active learning which most effectively supports long-term retention of knowledge.

**Emotional engagement**

Artistic activities elicit a variety of emotional responses and theatre is no exception (Ødegaard 2003; Dorion 2009). Emotional arousal renders learning more effective by engaging neural mechanisms involved with memory and attentional focus (McGaugh 2004; Phelps 2006; Immordino-Yang and Damasio 2007; Talmi et al. 2008). Hardiman (2010) noted the value of the performing arts for emotional arousal that enhanced learning.

In the case of science, creating space for emotions as well as cognition may narrow the dissonance between school science and students' cultural identities (Alsop 2001; Immordino-Yang and Damasio 2007). Scientific inquiry is reliant on objectivity to the exclusion of emotional involvement and personal perspectives. This can have the unfortunate consequence of rendering school science alienating for some students.

Positive emotions have important indirect effects on learning. Positive affect is associated with more creative and integrative thinking (Isen, Daubman, and Nowicki 1987). It enhances motivation and interest, both of which are integral to learning and comprehension (Ryan and Deci 2000). Enjoyment of science is strongly associated with interest in science and the desire to pursue it further (Ainley and Ainley 2011).

**Design and methods**

The effect of the intervention was evaluated with pre- and post-tests of knowledge and attitudes. An experimental design was not possible given the difficulty of recruiting schools for a control intervention, a common problem in educational research (Cohen, Manion, and Morrison 2007). A mixed methods approach, including questionnaires and interviews, was adopted to investigate the variables of interest.

**The play**

*Story of a Seed* was a 50-minute, two-actor play about plant reproduction, written by the lead author (a lecturer in plant sciences) and three members of the participatory arts company Blazing Tales (www.blazingtales.co.uk). The aim was to create a play that was funny and entertaining, aroused children's interest and appreciation of plants, and increased their knowledge about plant reproduction. The play script and other resources from the play are available online as supplementary materials.

The play is about two plants that encounter each other in a meadow. Arrogant Rosy Wylde (*Rosa canina*) intends to teach the children about botany and affable Gabriel Oat (*Avena sativa*) wants to help her. After a disagreement about which flower species is better than the other, Rosy and Gabriel embark on a journey to learn about how plants reproduce, becoming reconciled to their differences in the process. The characters investigate aspects of floral structure, pollination, fertilisation, seed dispersal and germination, using physical theatre,
stage props (a painted set and plant materials) and music (percussion, recorder and guitar) (Figure 1). The characters consult and interact with the audience as they strive to understand these concepts; a volunteer from the audience assembles the reproductive components of the flower, for example. After each topic, the characters sing a verse and chorus of The Ballad of the Seed which captures the key points in rhyming verse. The lyrics are displayed on a flipchart so that the audience may join in. The play also featured three participatory art activities: making a tissue paper flower (following the scene about flower structure), a creative writing exercise about seeds (following seed formation), and a rain-making sound dance (following seed dispersal).
Participants

The study was conducted with five primary schools in Devon (UK), two in an urban, one in a periurban and two in a rural setting. All participants were in Years 5 or 6 (9–10 years and 10–11 years, respectively). A prerequisite for participation was that the students had not yet studied key stage 2 plant reproduction from the UK national curriculum. We invited schools to participate via an email bulletin circulated to all head teachers of schools in Devon. Of the 10 schools that replied wishing to participate, we selected 5 schools. Schools were selected to produce a diverse sample in terms of pupil ability based on literacy and numeracy test scores (Department of Education 2017), socio-economic status based on the Indices of Multiple Deprivation (Ministry of Housing, Communities and Local Government 2015), and location (urban, periurban or rural). We ensured that the sample included schools from the upper and lower quartiles for each parameter. The play was performed in the school hall during lesson time as an enrichment activity towards the end of the school term.

Parents and legal guardians were sent an information sheet prior to the study, asking them to contact the school office if they did not wish their child to participate in the study. Participating teachers circulated (and read out) an information sheet to their students, which included information about how to withdraw from the study. We chose an ‘opt-out’ rather than ‘opt in’ system for consent because, in our experience, the return rate of school consent forms is poor, meaning a considerable number of children are prevented from participating in an enriching experience with their peers. Furthermore, the administrative burden associated with consent forms deters some schools from taking part in such studies. This method was approved by the Plymouth University’s Faculty of Science Ethics Committee and Schumacher College Ethics Committee.

Pilot studies

An initial pilot performance took place in December, 2014, at a university college, to an audience of 25 adults and children. These led to a number of revisions to the play. First, we realised that some of the jokes in the play were too adult for the target audience and so these were revised. Second, there were scientific inaccuracies in the improvised elements of the play that were corrected, for example, the mechanisms of pollen transfer in insect pollination. This issue was an unavoidable consequence of working with actors that do not have backgrounds in science and highlights the necessity of actor–scientist partnerships in science drama projects. Finally, the participatory activities were refined in terms of verbal instructions given prior to activity, timing and set layout.

A final pilot performance took place in March, 2015, at a rural primary school, to a mixed class of Years 5 and 6 (22 children). The play did not require any further revisions after this second pilot performance. The pre- and post-intervention questionnaires described below for Study 1 were used for the first time during this pilot study. No changes were made as the completion rate was deemed satisfactory for all questions

Studies 1 and 2

For Study 1, the play was performed twice in an urban primary school to the Year 5 and Year 6 classes, respectively, and once in a rural primary school to the Year 6 class, in December, 2015 (80 children).
For Study 2, the play was performed twice in a large urban primary school to separate Year 6 classes, and once in a smaller peri-urban primary school to the Year 6 class, in December, 2015 (64 children). The two studies were identical in all respects save for the format of the knowledge test portion of the questionnaires. In Study 1, the pre- and post-intervention questionnaires contained both multiple-choice and open questions, while in Study 2 they contained only multiple-choice questions. The open questions were omitted in Study 2 because completion rate was low (36.25% for a question about fertilisation and 71.25% for a question about seed dispersal). Study 2 added a final delayed post-intervention questionnaire six weeks after the event.

**Questionnaire**

Participants completed a questionnaire immediately before and after viewing the play. A subset of 27 participants in Study 2 also completed a questionnaire 6 weeks afterwards to measure the long-term learning outcomes (some of the children who viewed the performance were not available for the delayed post-test). The questionnaire aimed to measure the play’s effect on student knowledge achievement and attitudes to plant science, as well as interest and engagement with the play. Pre-, post- and delayed post-questionnaires had identical content for the knowledge and attitudinal sections. The post-questionnaire contained an additional section for feedback about the play. Teachers did not provide test answers or discuss content of the play in class until pre-, post- and delayed questionnaires had been completed.

In Study 1, the questionnaire’s content knowledge section required students to label a diagram of a cross section of a flower, complete two four-level multiple-choice questions about pollination and two open questions about fertilisation and seed dispersal, respectively. In Study 2, the questionnaire was revised to consist of eight five-alternative multiple-choice questions following the formats used in a number of previous studies (Peleg and Baram-Tsabari 2011; Kerby et al. 2010; Klepaker, Almendingen, and Tveita 2012).

The attitudinal section of the questionnaires in both studies comprised four statements about plants (‘I’d like to learn more about plants in Science,’ ‘learning about plants is difficult,’ ‘learning about plants can be fun,’ ‘plants are one of the most boring subjects in Science’), each with a four-level Likert scale (‘Not at all,’ ‘A little bit,’ ‘Pretty much,’ ‘Very much’). The attitudinal section was developed from questionnaires on attitudes to school biology in Prokop et al. (2007) and attitudes towards school science in Kerby et al. (2010).

The post-questionnaire of Study 2 also included a section that assessed student interest and engagement with the play based on Kerby et al. (2010). Students were asked to circle words or phrases that most accurately described what they thought of the play (‘annoying,’ ‘helped me learn,’ ‘too easy,’ ‘funny,’ ‘too difficult,’ ‘boring,’ ‘interesting,’ ‘didn’t learn much’). In addition, two open questions (‘what you liked most’ and ‘what you liked least’) invited the student to elaborate on their opinions about the play.

Questionnaires were completed in classrooms under test conditions. Students were not made aware of the schedule of testing ahead of time. Prior to handing out the questionnaire, the researcher stressed that it was not a test and that the questionnaire would not be seen by their teachers. This information was also written explicitly in the introductory paragraph of the questionnaire. Questionnaires were read aloud by classroom assistants to any children
with special educational needs. Children were allowed as much time as necessary to complete questionnaires. Completion times did not exceed 20 minutes in any of the trials.

**Data analysis – questionnaires**

For analysis of the multiple choice questions, each correct answer was assigned a score of one point and each incorrect answer, ‘don't know’ or uncompleted question was assigned zero points (Cohen, Manion, and Morrison 2007). For analysis of the open content knowledge questions (Study 1 only), each correct fact was awarded one point to a maximum score of six points for the seed dispersal question and six points for the fertilisation question.

The individual question scores were summed to yield a total score for each questionnaire. For each study, paired t-tests were used to assess the following comparisons: pre-test and post-test scores (short-term recall); pre-test and delayed post-test scores (retention); post-test and delayed post-test scores (persistance).

For analysis of the attitudinal section, positive statements ('I'd like to learn more about plants in Science; 'learning about plants can be fun') were assigned a score from 1 to 4, corresponding to the responses 'not at all'; 'a little bit'; 'pretty much' and 'very much' (Kerby et al. 2010). Negative statements ('learning about plants is difficult; 'plants are one of the most boring subjects in Science') were scored in the reverse direction, from 4 to 1. Therefore, for both positive and negative statements, a higher score indicated a more positive attitude towards plant science. Attitudinal data from Studies 1 and 2 were combined for the analysis and a repeated measures ANCOVA applied, with study number as a covariant. This follows Norman (2010) who argues that parametric tests are found to be robust for Likert data in similar studies.

For analysis of the two open feedback questions, an emerging theme analysis with no a priori categories were used (Cohen, Manion, and Morrison 2007; Peleg and Baram-Tsabari 2011). Feedback data from Studies 1, 2 and the final pilot were combined. Cronbach’s Alpha was used to measure internal consistency between the four attitudinal questions.

**Interviews**

In Study 2, 15 interviews were conducted with pairs of children from two of the participating schools, taking place one week after viewing the play. Their purpose was to supplement with richer detail the learning and attitudinal data from the questionnaires. Interviews were audio-recorded. The semi-structured interviews were roughly 10 minutes long and consisted of five leading questions about the play which had been informally tested and reviewed during the pilot phase. Children participated in interviews in pairs selected by the teacher, a format shown by Peleg and Baram-Tsabari (2011) to encourage active contribution and dialogue. The interviewer explained to the children that information in the interview would not be shared with the school and ensured that the interview pace and content was appropriate to age group.

**Data analysis – interviews**

Audio data from the interviews were transcribed and analysed qualitatively using an emerging theme analysis with a priori categories (Cohen, Manion, and Morrison 2007) based on the interview questions. The study authors independently identified emerging sub-categories through immersion in the data. Common subcategories were identified and these were
used for the final analysis. Krippendorff’s alpha was chosen as a reliability measure for inter-coder agreement as it is satisfies all key criteria for reliability and is specifically designed for content analysis (Hayes and Krippendorff 2007).

Results

Questionnaire – knowledge acquisition

Students were tested on their knowledge of plant reproduction before and after the play (Figure 2). Comparison of the pre and post tests showed a significant gain in knowledge scores in Study 1, \( t(80) = 10.479, p < 0.001 \), as well as Study 2, \( t(64) = 10.237, p < 0.001 \). Pre- and post-test scores were probably higher in Study 2, compared to Study 1, because of the higher completion rate (the two open questions in Study 1 were omitted by 36.25 and 71.25% of students, respectively).

In Study 2, a delayed post-test was given six weeks after the immediate post-test (Figure 3). Comparison of the post- and delayed post-tests showed no significant difference, \( t(27) = 0.406, p = 0.688 \), indicating that the knowledge gain evident in immediate recall persisted over the long term.

Questionnaire – attitudes to plants in school science

Attitudes to plant science were measured before and after the play using a four-level Likert scale (‘not at all’, ‘a little bit’, ‘pretty much’ and ‘very much’) for two positive and two negative statements about plants in school science. For analysis, responses were scored from 1 to 4, a higher value indicating more positive feeling, and data from Studies 1 and 2 were combined. Attitudinal data had a Cronbach’s alpha of 0.70 and 0.71, before and after watching the play, respectively, a satisfactory level of internal agreement between attitudinal statements (DeCoster and Claypool 2004). Attitudinal data could therefore be legitimately collated, to produce a single variable measuring overall attitude to plant science.

Children’s overall attitude to plants in school science improved as a consequence of watching the play as shown by a repeated measures ANCOVA, \( F(137) = 4.021, p = 0.047 \), although the improvement was not substantial (Figure 4). The co-variate, study number, showed no significant interaction with attitudinal data, \( F(137) = 0.453, p = 0.502 \), confirming that the differences in knowledge test did not affect attitudinal scores. A comparison of the four attitudinal statements suggests that the most substantial changes in attitude were for the statements ‘learning about plants is difficult’ and ‘learning about plants can be fun’ (Figure 5).

Qualitative data

Qualitative perceptions of the play and its affective and educational qualities were gathered through feedback in the post-play questionnaire and semi-structured interviews one week after the performance. The most common themes that emerged in the interviews are shown in Table 1. Data was analysed by the study authors (lead author frequencies are shown where assessor values differed). Krippendorff’s ordinal alpha is 0.991 (\( n = 21 \)), a substantial degree of reliability (Hayes and Krippendorff 2007).
Figure 2. Mean knowledge test scores before and after watching an educational play. (a) Study 1, $n = 80$. (b) Study 2, $n = 64$. Error bars = standard error.

Figure 6 shows the selection rates of descriptive terms that were circled in the questionnaire feedback, and Table 2 lists the types of answers provided to the open questions asking what was most and least liked about the play. These data are discussed in aggregate below.

Perceptions of learning

The majority of students (Figure 6) indicated that the play ‘helped me to learn’. Some of the factual information most frequently mentioned in the interviews were the role of bees in pollination and pollen grains in fertilisation. These two topics were particularly memorable aspects of the play. Bee pollination was demonstrated using stage props of a flower cross...
Figure 3. Mean knowledge test scores before, immediately after, and 6 weeks after watching an educational play (n = 27). Error bars = standard error.

Figure 4. Overall attitude to plant science obtained by combining response scores to four attitudinal statements. Error bars = standard error.

section, a bumblebee and the actors’ headdresses. The actors presented germination of the pollen as a piece of prose, with musical accompaniment. The journey of the pollen tubes to the ovary was conveyed in the style of a race commentary, whilst demonstrating the race of the pollen tubes using the stage props:

Ready steady go: thousands of tubes grow down the style. In the tip of each tube is a male sex cell. Pushing and growing as fast as they can – which one of them will win, who will get the girl? The strongest, the fastest, meets the ovule and, when the male cell inside the tip of the
Figure 5. Comparison of mean scores for four attitudinal statements, before and after watching an educational play. Attitudinal statements are 'I'd like to learn more about plants in Science,' 'learning about plants is difficult,' 'learning about plants can be fun' and 'plants are one of the most boring subjects in Science.' Higher score indicates a more positive attitude.

pollen tube meet the ovule, they become one. Male and female meet each other and it’s like the whole universe explodes as new life is created in that moment of fusion; the moment of fertilization; the birth of the seed.

This student compared how his teacher might have taught fertilisation, compared to the play:

I think sir would have probably have done, like, with the pollen; but done a line with his pen to say they were racing. But it wouldn’t have been the same.

**Song and music**

An aspect of the play that deserves special mention with regard to learning is the music. In questionnaire feedback, 24% of the children indicated that the thing they liked best was the play’s song, *The Ballad of the Seed*. More than half of the interviewees mentioned the song when asked about aspects of the play that helped them learn. For example: ‘the songs helped me remember parts of the flower;’ ‘the song, because it told me a lot;’ ‘they used songs to give a hint.’ The song was considered helpful for learning because it was ‘catchy,’ as this student explained:

Cause it’s got like a tune to it, the tune probably sticks in my mind and I find the words as I go along.

Interviewees found the song helpful for learning because hearing factual information in a rhyming style, accompanied by a melody, assisted recall:

It’s in like a beat so you can hum it and remember. In class we have to jot it down, put it back, get it out later and look at it. But it’s like you can feel the beat of it and just remember.
Table 1. Summary of themes identified in interview data, collected through 16 semi-structured interviews with 32 children.

<table>
<thead>
<tr>
<th>Theme/opinion</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitudes towards plant science</strong></td>
<td></td>
</tr>
<tr>
<td>Interviewee found plants boring, before seeing the play</td>
<td>46.88</td>
</tr>
<tr>
<td>Interviewee felt differently about plants after seeing the play</td>
<td>81.25</td>
</tr>
<tr>
<td>Seeing the play has made interviewee feel a greater appreciation for plants</td>
<td>62.50</td>
</tr>
<tr>
<td>Seeing the play has made interviewee feel more interested in plants</td>
<td>53.13</td>
</tr>
<tr>
<td><strong>Factual learning recalled from the play</strong></td>
<td></td>
</tr>
<tr>
<td>Methods of seed dispersal, for example expulsion, adherence to part of an animal, wind</td>
<td>31.25</td>
</tr>
<tr>
<td>The role of the pollen grains in fertilisation</td>
<td>28.13</td>
</tr>
<tr>
<td>The role of the bee in pollination</td>
<td>18.75</td>
</tr>
<tr>
<td><strong>Perceptions of different elements of the play and influence on learning</strong></td>
<td></td>
</tr>
<tr>
<td>The song had a positive influence on learning</td>
<td>56.25</td>
</tr>
<tr>
<td>The song helped learning because it was appealing and memorable ('catchy')</td>
<td>28.13</td>
</tr>
<tr>
<td>The song helped learning because singing was a fun or effective way of learning information</td>
<td>28.13</td>
</tr>
<tr>
<td>The song was enjoyable, relaxing or uplifting for its musical value</td>
<td>37.50</td>
</tr>
<tr>
<td>The flower cut-out helped learning because it was visual, interactive or both</td>
<td>21.88</td>
</tr>
<tr>
<td>The flower making activity was enjoyable, rather than educational</td>
<td>37.50</td>
</tr>
<tr>
<td>The seed poem was both enjoyable and educational</td>
<td>34.38</td>
</tr>
<tr>
<td>The seed poem was thought provoking</td>
<td>25.00</td>
</tr>
<tr>
<td>The seed poem was interesting because interviewee found out what other people thought, or had learnt, about seeds</td>
<td>21.88</td>
</tr>
<tr>
<td><strong>Opinions about the actors</strong></td>
<td></td>
</tr>
<tr>
<td>One or both actors were humorous</td>
<td>62.50</td>
</tr>
<tr>
<td>One or both actors were competent performers ('good')</td>
<td>31.25</td>
</tr>
<tr>
<td>Referred to the personality of one or both actors: Rosy as arrogant or spoilit and Gabriel as strict</td>
<td>18.75</td>
</tr>
<tr>
<td><strong>Perceptions of the learning environment of the play compared to the classroom</strong></td>
<td></td>
</tr>
<tr>
<td>Interviewee described the classroom environment using one or more of the following terms: completing a worksheet, looking at the board, listening to the teacher, writing notes, working from a book, 'just sitting'</td>
<td>40.63</td>
</tr>
<tr>
<td>The play was enjoyable ('fun'), rendering the factual information easier to learn or more memorable than in the classroom environment</td>
<td>34.38</td>
</tr>
<tr>
<td>The visual or demonstrative nature of the play made it easier to learn from, compared to the classroom environment</td>
<td>28.13</td>
</tr>
<tr>
<td>The classroom environment is boring</td>
<td>18.75</td>
</tr>
<tr>
<td>Respondent like the fact that did not have to work or undergo formative assessment during the play</td>
<td>18.75</td>
</tr>
</tbody>
</table>

An example of the rhyming style and factual content is shown in the following verses about fertilisation:

The sticky little pollen balls / Land on the stigma's end / Pollen finds a perfect fit / And grows a tube to send. / Down the style to the ovary / The pollen tubes then speed / An explosion and a fusion / The creation of a seed.

As well as finding the song helpful for learning, nearly half the interviewees also stated that they enjoyed the singing per se or that they found the music uplifting or relaxing. These two students described the singing thus:

I was nearly dancing my socks off.

You had some of the boys singing their heart out.

Songs with subject-relevant content have been used as learning tools for mathematics, biology and chemistry (Pye 2004; McCurdy, Schmiege, and Winter 2008; Crowther 2012;
Figure 6. Children's responses to a question that required them to circle words or phrases that described their thoughts of the educational play \((n = 133)\).

**Table 2.** Responses to two open feedback questions. Only responses with 5 or more respondents are shown, 166 children (pilot, Studies 1 and 2, \(n = 166\)).

<table>
<thead>
<tr>
<th>What did you like most about the play?</th>
<th>Percentage of children that gave response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive elements</td>
<td></td>
</tr>
<tr>
<td>The song/singing</td>
<td>24.10</td>
</tr>
<tr>
<td>Making a flower</td>
<td>19.88</td>
</tr>
<tr>
<td>The participatory activities</td>
<td>3.61</td>
</tr>
<tr>
<td>The characters or content</td>
<td></td>
</tr>
<tr>
<td>The play or actors were humorous</td>
<td>12.05</td>
</tr>
<tr>
<td>Gabriel Oat</td>
<td>5.42</td>
</tr>
<tr>
<td>The acting/actors</td>
<td>3.61</td>
</tr>
<tr>
<td>The disagreement between the characters at the beginning</td>
<td>5.42</td>
</tr>
<tr>
<td>Quality of learning</td>
<td></td>
</tr>
<tr>
<td>The play made learning enjoyable ('fun')</td>
<td>4.82</td>
</tr>
<tr>
<td>Learning about plants/flowers</td>
<td>3.61</td>
</tr>
<tr>
<td>It was interesting</td>
<td>3.01</td>
</tr>
<tr>
<td>What did you like least about the play (or could have been better)</td>
<td></td>
</tr>
<tr>
<td>I liked all of it/nothing needed changing</td>
<td>39.76</td>
</tr>
<tr>
<td>The song/singing</td>
<td>5.42</td>
</tr>
<tr>
<td>The disagreement between the characters at the beginning</td>
<td>3.01</td>
</tr>
</tbody>
</table>

Lesser (2015). Like Crowther and Pye, we placed song verses at strategic points in the educational intervention as a way of summarising the preceding factual content. Crowther and Davis (2013) postulated that educational songs assist learning in a number of ways. They help to integrate working memory into long-term memory, particularly if the song evokes emotions. The metre and rhyme scheme restricts the choice of words that can be fit to a
song, which assists recall. Repetition of verses strengthens information in memory. Finally, song produces rich memories by engaging multiple modalities: auditory music, the kinaesthetic act of singing, the visual nature of reading lyrics and watching actors sing. Crowther (2012) also proposed that the relaxing and welcoming nature of song had a positive effect on learning.

**Emotions evoked by the play**

Although the emotional content of the drama was complex, positive emotion was most prominent. The play was described as ‘funny’ by 80% of the children and 12% mentioned humour as their favourite aspect (Table 1). The most common remark made about the actors (63%) was that they were humorous. The play was replete with jokes and innuendo. An excerpt from the opening scene in which the characters criticise their botanical differences, one being a rose and the other a grass plant:

- Gabriel Oat: I may be dull but I’m definitely dependable. Anyway I’m not sure I can trust you; you pop children’s balloons.

- Rosy Wylde: You’re so insignificant; nobody even notices you. I’ll end up walking all over you like everybody else does.

Garner (2006) observed that humour incorporated into statistics lectures increased enjoyment and recall compared to a control treatment. Garner proposed that the potential benefits of humour included relaxation and anxiety reduction, the physiological benefits of laughter and creation of a cognitive break between information delivery episodes. Educational science drama projects have often highlighted the important element of humour (Dorion 2009; Kerby et al. 2010; Peleg and Baram-Tsabari 2011). Communication methods that evoked positive emotions in the recipient render the information linked to these emotions more memorable (Negrete 2002).

School science is more accessible if it is compatible with learners’ personal identities (Lemke 2001; Warren et al. 2001). Learners tend to be more interested in things that relate to their existing experience and drawing on human interest is a particularly valuable motivational tool in science education (Keller and Burkman 1993). Bowker (2004), for example, found that students’ interest in a botanical garden was enhanced by pointing out the relevance of the plants to chewing gum and chocolate. In *Story of a Seed*, Gabriel Oat mimics a kick-off at Wembley Stadium to highlight the importance of grass species to mankind, eliciting enthusiastic responses from the many football fans in the audience.

**Learning environment vs. classroom**

When asked how they thought the play compared to the classroom, many of the interviewees (41%) described the classroom in terms of a teacher-centred, instructivist environment (Table 1), for example:

- We would have just like looked at the board, seen what information was on it and jotted it down.

Thirty-four per cent of interviewees said that the play was enjoyable, rendering it easier to learn from than classroom instruction. The novelty of the play, or the fact that it was not perceived as work, obviously contributed to children’s enjoyment, as this example demonstrates:
But what you did – what your actors did – is a different way. I hadn’t experienced it before: so it was a different way, and it was more information, but in a nice, enjoyable way. Rather than: ‘get your jotter out, jot things down’ and – all that way.

The value of the non-verbal forms of communication for supporting learning, for example, percussion, physical theatre and stage props, was a theme that arose throughout the interviews. The visual and demonstrative qualities of the theatrical medium can help to communicate abstract concepts or ideas in science, which children find difficult to visualise (Winston 2008; Kerby et al. 2010; Peleg and Baram-Tsabari 2011). One student described her experience thus:

Well, I would have learnt more in the play [than the classroom] because you could see more; but if you said it in words then it would be a bit confusing. But because I’ve seen, like, the sculptures, the art and how they move it, how they travel, how the plants (and inside of it) and the pollen and the bees, yeah, but in a lesson we would just obviously just find out, like, how it would move. We wouldn’t actually see it for ourselves.

Another student compared the stage prop of a flower cross section to the whiteboard in the classroom:

I thought they [the stage props] were very interesting because, instead of drawing a big diagram, you’ve got a model of a flower and you’re actually moving it around; makes it even more interesting.

**Participatory art activities**

The play included three interludes during which children took part in art activities on the theme of plant reproduction. The first involved crafting a tissue paper flower. The second was a creative writing exercise where the groups composed a sentence starting with the words: ‘a seed is …’ The actors read these sentences in random order in the style of a poem. The third was a rain-making sound dance. The flower creation was particularly popular with 20% of students citing it as their favourite aspect of the play (Table 2). Many students felt that the flower crafting (22%) and poem writing (34%) benefited learning. 22% students described the exchange of ideas with peers in the latter activity as thought-provoking, for example:

It was really interesting and funny about what other people thought about plants, and what they now think about seeds after learning about them a bit more.

These departures from the main activity of the performance might be beneficial in several respects. Rinne et al. (2011) described how creating a work of art on a particular topic requires students to create a background context for learning, which enhances memorisation, an effect they describe as elaboration. The art activities provided an opportunity to recall and reflect upon things learned earlier, an effective technique for long-term retention (Roediger and Pyc 2012). Even if the activities contribute more to enjoyment than learning, breaking up a lesson at strategic points can help to sustain student attention (e.g. Prince 2004).

**Attitudes towards plants**

Children’s overall attitude to plants in school science, as measured by a Likert scale, significantly improved as a consequence of watching the play, although the increase was not substantial (Figure 4). Most of the children interviewed (81%) claimed to feel differently
about plants following the play. Many said that they had previously found plants boring (47%), describing plants in passive terms: ‘they are just there’ or ‘they don’t really do much’. Plants were now perceived as adaptable, intelligent and intriguing, as these two examples demonstrated:

Before the play I thought plants were quite dull and boring, after play it kind of gave a whole different side of the plants.

You don’t really know what is going to happen about them like how they are what they do and stuff. You can’t really say: ‘oh, that was going to do that; you have to wait and see.’

Some children felt that learning more about plants increased their interest in them:

Now I know more about plants I think they’re more interesting. I learnt a lot from the play and that’s what got me into it.

This is a notable outcome given the frequency with which the declining interest in plants is highlighted in the biological education literature (e.g. Drea 2011; Levesley et al. 2014). Other interventions that have been shown to have a positive effect on attitudes towards plants are visits to botanic gardens and experiential outdoor programmes (Bowker 2004; Lindemann-Matthies 2006; Sanders 2007; Fančovičová and Prokop 2010).

Conclusions

Story of a Seed demonstrates the potential that an interactive theatre production offers for enhancing appreciation and interest in plants and plant science. Questionnaire and interview data both indicated an increase in positive attitudes towards plants among the students. Given concerns about declining interest in science in the post-primary school years, this form of early intervention has value by itself. However, the experience was shown to have lasting educational value as well. Learning about plant reproduction was evident in tests of immediate recall, and this knowledge showed long term retention when tested six weeks later.

As anticipated from the theoretical stance of the study, emotional engagement played a key role in supporting children’s learning and interest development from the play. The main emotional responses to the play were enjoyment and humour, which can be attributed to the musical content, the comic behaviour of the actors and the participatory activities, as well as the general experience of the theatrical performance. In contrast, there was little evidence that the play’s narrative contributed to learning or interest, The plot structure was not particularly complex in Story of a Seed so this may explain why narrative did not form an important part of the educational experience. However, the use of metaphor in the play was found to support learning. Non-verbal forms of communication, namely music, physical theatre and stage props, assisted children’s understanding of biological concepts and processes in the play, for example, pollen grain movement and floral structure. These findings highlight the value of integrating arts-based activities into science education, for producing positive affect and supporting conceptual learning. Arts-based activities could be used as cognitive breaks between episodes of information delivery, for example, in the form of a thematic song or a participatory art activity, like those created for Story of a Seed.

An appealing feature of educational theatre and other dramatic activities is their accessibility, relatively low cost and that the activity can take place on the school premises. Although our production of Story of a Seed used professional actors, the expense was
moderate when one considers the numbers of students engaged with multiple performances at different sites. Out-of-class educational experiences like these are most effective when delivered in conjunction with class-based learning before and after the experience (Bowker 2004; Peleg and Baram-Tsabari 2011). Moreover, the materials of Story of a Seed could be utilised independently by schools. For example, the script and Ballad of the Seed song could be used as the basis of a student production. In conclusion, we propose that this study provides compelling evidence for the benefits that art-based activities in science can provide alongside inquiry-based ones.

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References


