

Constructing creativity: secondary school pupils designing and building musical instruments with LEGO®

Ross Purves
Institute of Education,
University College London
20 Bedford Way, London WC1H 0AL
r.purves@ucl.ac.uk

Nicolas Gold
UCL Computer Science,
University College London
Gower Street, London WC1E 6BT
n.gold@ucl.ac.uk

Evangelos Himonides
Institute of Education,
University College London
20 Bedford Way, London WC1H 0AL
e.himonides@ucl.ac.uk

Dan Wang
Institute of Education,
University College London
20 Bedford Way, London WC1H 0AL
dan.wang.20@ucl.ac.uk

Abstract

STEAM (Science, Technology, Engineering, Arts, Mathematics) education is increasingly used to engage and motivate children. Effective STEAM education requires an integrated approach in which all aspects have equal value and importance to the task being attempted as this maximises the opportunities for students to pursue aspects of particular interest. This paper reports on a musical-instrument design activity embedded within STEAM workshops and intended to provide inter-disciplinary learning opportunities. The workshops involved secondary school pupils designing and constructing their own functional, acoustic musical instruments using LEGO®. A total of 61 pupils from six schools worked in small groups to create playable instruments, drawing on a range of building approaches that included free construction, visual prompts, and detailed instructions.

The activity proved to be highly motivating for participants and offered rich opportunities for creative exploration and musical expression. Through the processes of designing, adapting, and assembling LEGO®-based acoustic instruments, pupils addressed a variety of aesthetic, structural, ergonomic, and acoustic considerations. These hands-on challenges supported reflection on problem solving strategies, design trade-offs, and the physical principles underlying sound production.

The workshops culminated in collective music jam sessions with the researcher-facilitators, which enabled pupils to experience the communal musical potential of their constructions and to connect the

processes of designing, building, and performing. Based on detailed analysis of a sample of 30 instruments, the paper illustrates how instrument building with LEGO® and similar 'visuo-spatial constructive play objects' can provide an engaging and educationally valuable context for creativity, collaboration, and integrated STEAM learning.

Keywords

visuo-spatial constructive play objects, musical instruments, STEAM education, LEGO®, instrument design

1 Introduction

This paper reports on musical instrument design and performance activities that formed part of two practical workshops in which secondary pupils designed and constructed their own functional, acoustic musical instruments using LEGO®. The workshops formed part of a long-term interdisciplinary research programme that blends both acoustic and digital musical instrument (DMI) making [1][2][3]. Accordingly, the workshops which form the focus of the present paper also included separate activities where pupils designed and constructed DMIs, described elsewhere [3].

This paper explores the musical and educational potential of making and music within integrated Science-Technology-Engineering-Arts-Mathematics (STEAM) learning.

1.1 THE STEM and STEAM movements within school-age education

Our work is framed in the constructionist tradition of education established by Papert [4] and within which we privilege relationality and care (after Noddings [5]) as foundational principles of education. Constructionism is oriented around the creation of a public entity [6] through and around which learning takes place and knowledge is constructed. Whilst this does not have to be a physical entity, the making of physical objects is a way to holistically engage learners,



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create a manifest purpose for an activity, and provide a deep and wide space of material and cognitive opportunity in which learners can find their 'home'. Eisenberg and Eisenberg [7] argue strongly in favour of the physical over the virtual in the context of constructionist education.

Whilst STEM (Science, Technology, Engineering, Mathematics) integration has been a relatively long-standing movement in education, STEAM is a more recent development and Yeomans et al. [8] argue that it is currently light on theory. Graham [9] summarises arguments made for the benefits of STEAM, e.g., it makes STEM more engaging and attractive to students and can catalyse innovation for economic competitiveness. Yet there are also concerns about this motivation in that market-orientations neglect the deeper purposes of art and education [9]. The risk of using arts as mere motivation for STEM approaches is that the arts can be trivialised as 'utility disciplines' [8].

Using arts as solely motivational is not just a problem of cultural value and disrespect, it contradicts the underlying principles of constructionism. Papert points out that the aim of constructionism is not to provide better motivation for children to learn, but instead to reconfigure the learning environment to remove barriers and pre-conceptions they hold that obstruct learning [4]. So whilst this may superficially appear as better motivation manifesting as greater engagement (and indeed, we have seen this emerging in our own work), the roots of that engagement lie not necessarily in finding motivation *for* children but instead, letting them find their own purpose within the learning environment. Eisenberg [10] argues strongly for purpose as the primary motivation in constructionist education (rather than skills development which he argues will be the by-product of purposeful activity). Constructionism thus aligns well with – indeed we argue that it *requires* – equality of disciplinary respect within STEAM.

The key mechanism within constructionism is Levi-Strauss's [11] concept of bricolage (tinkering). In other words, children need to be able to experiment within their learning environment and that environment must, as Papert describes, impose minimal constraints on the exploration of combinations of materials even though the materials themselves have constraints [4]. Graham [9] claims that STEAM education with an integral arts component involves the kind of experiential learning that might occur in a studio or laboratory. So, at a pragmatic level, the combinations may simply be explorations of, for example, how bricks connect. At a disciplinary level, one might conceive of these combinations in terms of inter- or cross-disciplinary moves.

Ness and Farenga [12] define Visuo-spatial Constructive Play Objects (VCPOs) as materials used to model what is imagined and construct something in the world of the person imagining. Ness [13], in work on early years development through play, discusses the affordance provided by VCPOs, indicating that the more 'scripted' a VCPO, the

higher affordance it has because it would typically have a known end state and detailed instructions. Unscripted VCPOs have lower affordance and thus encourage exploration. We argue that LEGO® (the VCPO we use here) has high affordance at the level of block assembly, but low affordance at the level of addressing the purpose of that assembly.

Harriman [14], in the context of DMI design in education, identifies several open research questions including determining appropriate levels of scaffolding to best facilitate learning. This question is relevant beyond the domain of DMI, and we consider it here in relation to acoustic instrument construction. Since scripting (i.e. instructions) is an important determinant of affordance [13] and by implication, affects the freedom and/or direction of bricolage, it was important to explore students' choices about the level of direction they prefer and the consequent impact on the outcomes of their exploration. This reflects the constructionist emphasis on following the learner and allowing them to drive their own exploration.

1.2 Designing and constructing musical instruments as educational and musically creative activities for school-aged children

Our previous work in this area [1] has suggested that designing and building musical instruments can present pupils with potentially rich educational opportunities, strongly grounded in creative and musical expression. Others have also pointed to the educational and creative potential of designing and building musical instruments within STEM- and STEAM-oriented school curricula. For instance, Hauze and French [15] found that a 50-hour electric guitar building project resulted in significant improvements in participating 11-18 school pupils' maths and science test scores. Cheng et al [16] reported benefits to elementary school aged pupils' individual and group creativity skills associated with a six-week ukulele building activity. In a commentary on these kinds of potential benefits, Ramsey [17] noted that 'music provides the connection of [STEM] elements with a topic that interests the students and motivates their learning' (p.1106).

Conversely, however, others in the field [8][18] have argued that—across the STEM and STEAM fields as a whole—evidence and/or theory remains relatively sparse regarding the contribution made to individual creativity and education as a whole. We hope that this present paper contributes to strengthening the evidence base, but also serves to emphasise the parity of the 'A' in STEAM. Whilst we regard the potential educational benefits as extremely valuable, we are equally focused on the expressive richness of making musical instruments and the inherent purpose this provides, both in terms of the sound that can be produced and how this contributes to collective music making, but also any perimusical decoration applied to the instrument.

1.3 LEGO® as a construction medium for musical instruments

Building on our earlier work [1], and noting its potential to function as an appropriate VCPO, we employed LEGO® as the construction medium for these workshops. Within the international ‘adult fans of LEGO®’ community, there is a tradition of constructing playable musical instruments [19] and, in the process, overcoming some of the inherent acoustic limitations of this ABS plastic medium. In a separate strand of research, we have produced an organological typology of these instruments [20] and observe that whilst viable instruments are possible using *only* LEGO® components (what we term a ‘pure’ type), other makers have constructed more complex designs augmented with non-LEGO materials and also DMIs featuring LEGO® Spike and EV3 sensors and switches.

We are not the first to employ LEGO® in educational, acoustic musical instrument building. Wendell et al [18] developed a nine-lesson scheme of work on the physics of sound and instrument design for 8 to 10-year-old school children. This made use of LEGO®, augmented with additional craft resources such as rubber bands and balloons, culminating in pupils designing their own instrument capable of playing three different pitches. This was designed a ‘series of guided design-based investigations’ (p.148) with supporting lesson plans and pupil guides. In our case, pupil workshops took place over a single session, and so we sought to investigate pupils’ perceptions of the role and utility of the provided instructional resources to scaffold their construction of a viable LEGO® musical instrument over a much shorter timescale than had been the case in Wendell et al.’s work.

1.4 The role of instructions within STEAM activities

Previous research with a range of learner age groups has highlighted the importance of designing appropriate instructional resources to support effective science and technology education, for instance in relation to promoting dialogue and critical thinking skills [21], maximising learner motivation [22] and balancing tightly-defined instructive steps with looser, illustrative exemplars [23].

In preparation for the LEGO® instrument workshops reported here, we developed three kinds of instructions to aid pupils, who were free to choose which type to use—or not to use them at all. The three kinds were: ‘Inspiration’ - featuring colour images of examples of previous instruments made from LEGO® during earlier fieldwork[1]; ‘Launchpad’ – a simple text/visual prompt for a how LEGO® instrument might be constructed; ‘Step-by-Step’, featuring detailed, sequenced instructions for realising a complete instrument (a box shaker). The names were chosen deliberately to reduce connotations of hierarchical complexity and ameliorate embarrassment perceived to be associated with relying on greater instructional guidance.

1.5 Research questions

Whilst intended to be educationally and musically valuable and enjoyable experiences in their own right, we also designed the LEGO® instrument workshops as a research exercise, intended to answer the following questions:

- RQ1: What were the observable properties of the instruments which were built?
- RQ2: what could be conjectured about students’ learning / expression through instruments that they constructed?
- RQ3: Was there any observable relationship between the instructions and models created?

2 Methodology

2.1 Practical workshop plan

Two in-person pupil workshops were held at our university a week apart. Six secondary schools were invited to participate based on previous professional collaborations (three schools per workshop). Each school brought around ten pupils, all aged between 11 and 13, so that—over the course of the two workshops—a total of 61 pupils took part, accompanied by their teachers. Given our intention for these workshops to be musically and educationally enriching in their own right and not just a research data collection exercise (see ‘Ethical Standards’) we had a series of learning objectives for the acoustic-based activity and these were reflected in the way we introduced the activity for pupils: these involved learning about instrument design, ergonomics and acoustics and associated engineering and musical trade-offs (see [1] for details on related objectives for previous fieldwork). However, our constructionist theoretical stance required limiting further direct instruction/guidance, relying instead on facilitative but open-ended scaffolding. Additionally, given the time available, we elected to focus on ‘pure’ LEGO® instruments, which resulted in a focus on constructing percussion instruments. Whilst previous rounds of our fieldwork [1] had also included non-LEGO® components including rubber bands to good effect, time was too tight and supervision too restricted to be able to include them in the workshops reported here.

Following our introduction, around one hour was allocated to the building activity, with pupils working in groups of four or five across three different rooms. Each room was set up in the same way, with clustered tables covered with tablecloths (to reduce noise levels and LEGO® sliding onto the floor [24]), on to which large open trays of general, mixed LEGO® components (e.g. bricks, plates, TECHNIC® components and decorative items of different shapes, colours and sizes) were placed. Since only an hour was available, and given the importance of pupils building a viable instrument within this time, three additional trays of specific types of LEGO® components were also provided to save time and offer additional scaffolding if required. One of these was filled with very small parts which could be useful to fill shaker-type instruments. Another was filled with large, thin-walled sectional pieces, such as castle walls, cylinder pieces and larger rock pieces. These could be used in the construction of large shaker or drum chambers. A third provided a supply of small base boards (described in more detail below).

At the end of workshops, all pupils gathered together to ‘jam’ with their acoustic instruments. Building on our previous fieldwork [1], we

regarded this as an extremely important part of the workshop's design, offering pupils an expressive opportunity to connect the activities of design, building and playing: not only did this musical performance represent a 'field test' of the technical effectiveness of pupils' instruments, it also conferred authenticity of musical and motivational purpose on the day's activities—informed by widely accepted current practices in music education which prioritise sound as the primary medium of musical engagement [25]. Additionally, and reflecting the NIME 2026 conference theme, it afforded a strong sense of community, with pupils from different schools playing together in a shared music-making experience. Playing along on piano, guitar and flute, the three facilitator-researchers taught pupils a simple salsa 'groove' featuring son clave and tumbao rhythms allocated to the different types of LEGO® instrument. Together we improvised musical structures featuring contrasting dynamics and sectional breakdowns, building to a fortissimo tutti finale. These performances were audio recorded so that they could later be shared with the schools in the form of a slide show featuring pictures of the constructed instruments as a memento of the day (see 'Ethical Standards').

2.2 Data collection methods

Each participating pupil was issued with a badge with an individual, anonymously allocated code. They added this code to the various questionnaires completed during the day, including two relating to the acoustic LEGO® instrument building activity: a pre-activity questionnaire asked them about, *inter alia*, their choice of instruction type, whilst a post-activity questionnaire asked, *inter alia*, whether they had stuck with this choice, and their reasons for changing if not.

Pupils subsequently fixed a sticker with their code to their instrument, enabling us to triangulate these with questionnaire content. In total, 61 instruments were created over the course of the two workshops but only 51 were still intact by the point of analysis.

2.3 Data analysis

Armitage et al. [26] provide a framework for categorising DMIs at macro, meso, and micro levels. Whilst their work was focused on digital instruments, a contribution of the present paper is to apply this same essential framework to acoustic instruments, constructed entirely from LEGO®. Armitage et al.'s macro level is concerned with the 'forms and functions of instruments across ecologies' (p.2), whilst the meso level defines 'configuration and mappings across taxonomically similar instruments' (ibid.). At the micro level, concern shifts to the 'subtle and detailed nuances between otherwise identical instruments' (ibid.). This framework was highly applicable to our research questions, enabling us to foreground the subtlety and detail in the pupils' constructed instruments. It is these subtleties and details which, note Armitage et al, 'are fundamental to what makes musical instruments special, and worth dedicating a life's practice to, for designer, maker, player and listener alike' (p.1).

A sample of 30 of the 61 instruments was audited to provide the basis of the meso- and micro-level analyses. Instruments were clustered by type and categorised according to Armitage et al.'s framework using rich, qualitative descriptions. These descriptions were then imported into SPSS data analysis software and linked to collated data on instruction choice.

3 Results and discussion

3.1 Macro categorisation of pupils' instruments

At the macro level, there were three basic 'forms and functions' evident in full set of 51 instruments left intact after the workshops. These are categorised in figure 1.

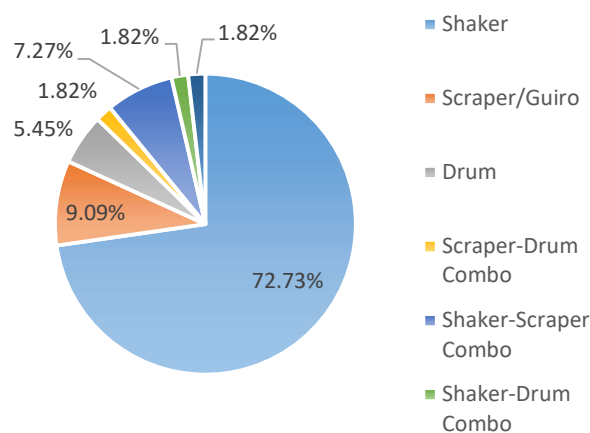


Figure 1: Distribution of the identified 'macro' level instrument categories in the 51 extant LEGO® instruments

As can be seen, the most popular basic choice of instrument type was a shaker (72.2%). Considerably smaller numbers of pupils elected to make scrapper style instruments (9%) and drums (5.5%). Small minorities of pupils produced hybrid forms, embracing shaker-scrapper, scrapper-drum, shaker-drum and shaker-scrapper-drum combinations.

The preference for shaker-type instruments may well have been influenced by the type of instructions chosen by pupils. As can be seen in Table 1, the majority of pupils whose shaker instruments were sampled for detailed analysis chose to use the 'step-by-step' instructions, which guided them to produce a shaker-based instrument. A smaller proportion opted for the 'inspiration' option, which included several pictures of different forms of shaker. In both cases, however, many pupils diverged from these forms of guidance at the meso and micro design levels.

	Total instrs.	Step-by-step	Inspiration	Launchpad	More than one type used
Shaker	38	42%	32%	13%	13%
Shaker-Scraper	4	0%	100%	0%	0%
Scraper	3	0%	100%	0%	0%
Drum	3	0%	67%	0%	33%
Scraper-Drum	1	100%	0%	0%	0%
Shaker-Drum	1	0%	0%	100%	0%
Shaker-Drum-Scraper	1	0%	0%	100%	0%

Table 1: ‘Macro’ level instrument categories for all 51 extant instruments cross referenced with the makers’ choice of instructions type

The three pupils making scraper-based instruments reported using the ‘inspiration’ instructions exclusively; these featured an image of a simple instrument of this type. Whilst two of the three who made drums also used the ‘inspiration’ set, it is notable that these did not include an explicit drum example – and this might explain why the remaining drum builder shifted between instruction types, using both inspiration and launchpad (the latter containing an image of a chamber based design which could easily become a drum).

Seven pupils constructed instruments that had viable combined functionality. These collectively drew on all instruction types, suggesting that pupils had taken different aspects of these to develop in their own ways.

3.2 Meso-level diversity in pupils’ instruments

A wide range of meso-level diversity was in evidence within the sample – much of which was closely linked to basic instrument type, but some forms of variation were observed across all three types, and these are discussed collectively.

3.2.1 Meso-level variation within shakers

Given that this was by far the largest group of instruments represented in the sample, there was significant variation in evidence.

A key meso-level characteristic was the choice of material used as the base, sidewalls and top of the shakers. The most common component used for the base was, perhaps unsurprisingly, a thin LEGO® base board. Due to their thinner form, these can vibrate more freely than

other types of LEGO® ‘plate’ component, contributing to reasonably effective tone and projection (e.g. figure 2). However, larger plate components (e.g. 8 studs x 8, or 16 x 16) were still employed in other designs and remained effective, despite being slightly thicker than base boards (figure 3). Plates were also the most common form of shaker ‘top’, used to seal the shaking chamber or ‘shell’ itself. There was more variation in sidewalls. Many shakers featured simple ‘stud-up’ sides constructed of standard blocks (e.g. figure 3). When the bond pattern used was effective (see section 3.2.4) this could result in very strong walls, capable of withstanding vigorous shaking. Other pupils had made use of the provided stocks of large LEGO® components naturally shaped to facilitate storage of the shaking media or ‘pellets’, including cylinder pieces, the castle walls and large pieces referred to within the ‘Adult Fans of LEGO’ community as ‘Big Ugly Rock Pieces’ (BURPs) (e.g. figure 4). As with the base plates, these larger, shaped components are naturally thinner, contributing to greater resonance and sound projection.

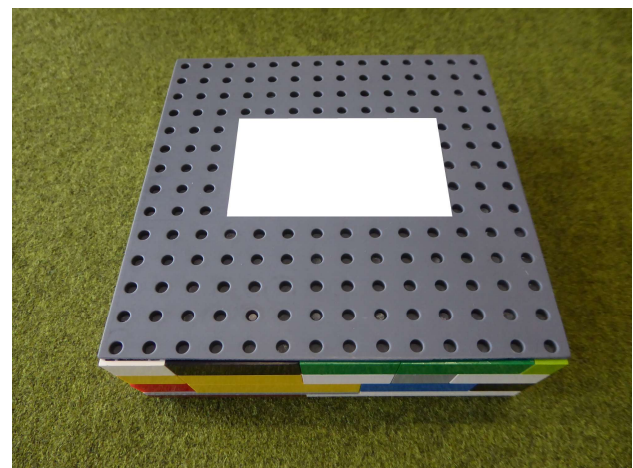


Figure 2¹



¹ As an additional data protection strategy, the allocated pupil ID numbers have been removed from images of the instruments.

Figure 3

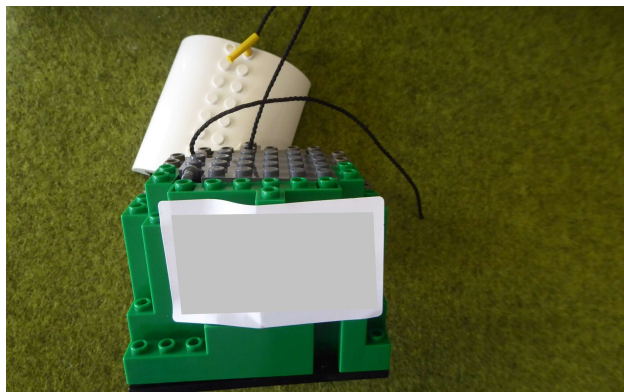


Figure 4

A second meso characteristic of the shakers related to the size of the shaking shell (compare figures 2-4). Many pupils had chosen to build these based on the dimensions of the provided base boards (14 studs by 14) or large plates. This could result in shakers with large horizontal dimensions but not necessarily vertical ones (leading to less effective sound projection from vertical shaking). The most effective designs were those with sufficiently high sidewalls to enable the pellets to move freely in all directions. Associated with this were pupils' choice of pellets themselves – most drew on our supplies of tiny pieces or augmented these with others they had found. Less musically successful instruments featured too few or too many pellets or used components too big to enable free movement within the shells.

A subset of shakers featured vents in the sidewalls, created either using components featuring holes (e.g. TECHNIC® bricks) or through leaving spaces between components. When carefully done, this could improve timbre and sound projection, but some designs featured too large holes, meaning that pellets fell out when the instrument was shaken. In some cases, the researchers suspected that these holes had occurred through mismatched components.

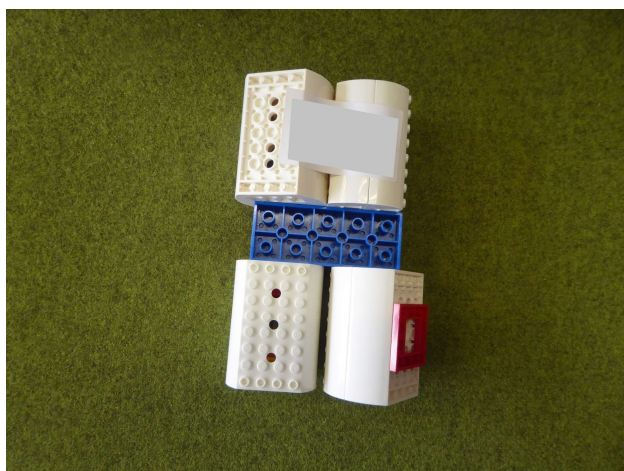


Figure 5

A final important meso-level characteristic of the shaker instruments related to the number of shaker shells employed within a single instrument. Most featured only a single shell, but some employed two to four independently filled shells which were connected in some way (e.g. figure 5). The latter group were amongst the most musically effective, resembling instruments such as the Ghanaian 'double caxixi'.

3.2.2 Meso-level variation within scrapers

Amongst the scrapers and scraper hybrid designs, the main meso-level difference related to the type of LEGO® component used as the serrated surface over which the scraping object was dragged.

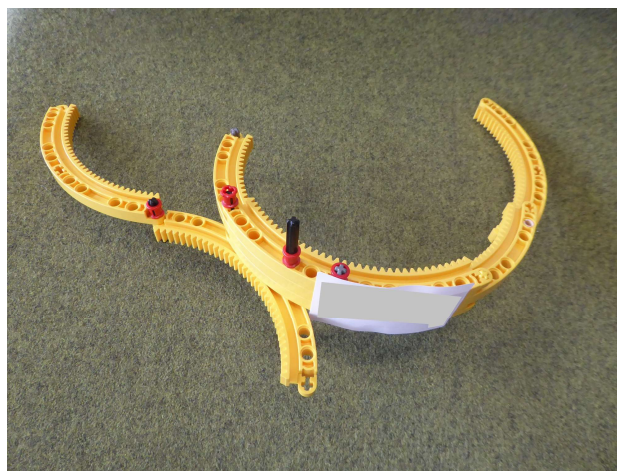


Figure 6

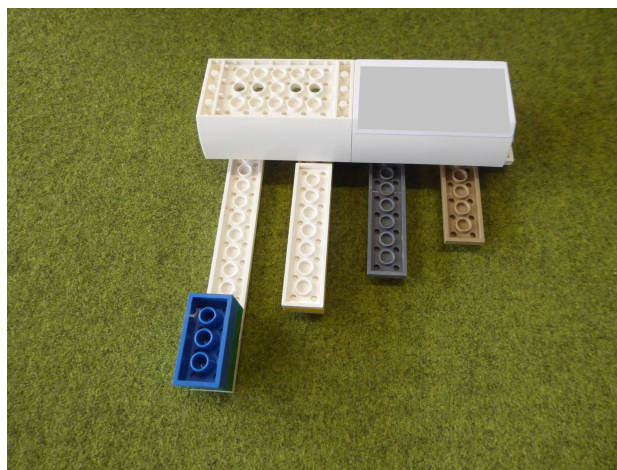


Figure 7

Some of these instruments employed curved gear racks designed by LEGO® as components for their excavator sets (e.g. figure 6). In a further case, the excavator bucket from this same origin set was employed by the pupil, with its integral teeth used as the scraping edge. In other scraper instruments, pupils had employed standard LEGO® 'studs' as the serrated surface. One such instrument called for the player to drag the scraping object over runs of LEGO® blocks or different lengths, whilst two employed two-stud wide plates of different lengths. In terms of timbral quality, the plate designs were

most successful; left free to vibrate at one end, the tone produced by these plates as they were scraped varied in accordance with their length – in a similar fashion to lamellae on plucked idiophone instruments (e.g. figure 7). By contrast, the design which employed runs of blocks was less musically successful as their ridged fastening to the base plate, together with their thicker form, effectively muted the sound.

3.2.3 Meso-level variation within drums

All three drums in the sample employed the provided thin LEGO® base plates as a strikable ‘batter head’, leveraging the same benefits as noted above for the shakers. The key design distinction within the observed drums related to the presence of an opposite, resonant head. In one drum this was entirely absent, but others were ‘ported’, meaning that this head was more of a lip around the frame with an open sound hole in the centre (figure 8). In the most musically effective example of this design, the resulting sound was more akin to a bright and loud wood block timbre.

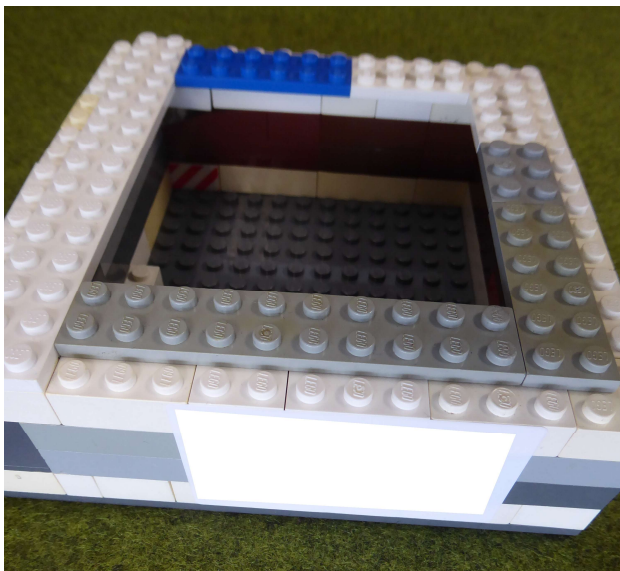


Figure 8

3.2.4 Meso-level variation across the sample as a whole

A subset of meso-level variations was applicable across instrument types and so are treated together. One such area related to the different construction techniques and/or block ‘bond patterns’ used by pupils. Relationships between the various bond patterns used in architectural brickwork and the structural strength these afford often go unconsidered by learners [27]. Correspondingly, there was significant variation in the consistency and structural appropriateness of the bond patterns used across the LEGO® instrument sample. Many instruments featured elements of ‘running bond’ (where rows of bricks are offset half a length from those above and below) but this strengthening practice was often inconsistently applied, interspersed with weaker, irregular configurations of bricks and the use of structurally-flawed ‘stack bond’ (where bricks are arranged vertically

with no offset) (e.g. figures 3 and 8). Similar structural weaknesses were observed in the tops of some shakers, where small LEGO® plates were tiled to close up a shell but then not overlapped with further plates (e.g. figure 3). In a minority of more seriously structurally compromised instruments, these issues led to their breakage during the final musical performance. However, most were robust enough to endure shaking, scraping and striking to a reasonable degree, and some were very strong indeed.

As observed in a previous round of fieldwork [1], one area where choice of construction technique was particularly important related to the inclusion of handles. In LEGO® instruments resembling maracas and guiros etc, the point at which the handle met the main body of the instrument was a significant stress concentrator and subjected to significant torque as the instrument was played. Instruments differed in how well they were designed to withstand this (e.g. figure 9).

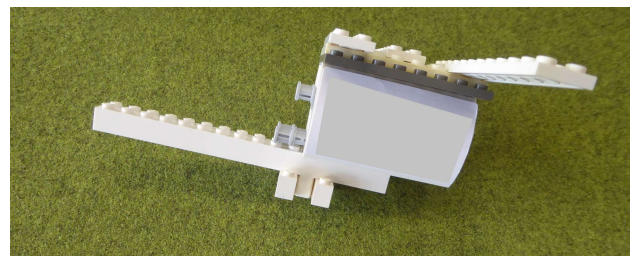


Figure 9

One in particular offered a novel approach involving a so-called ‘stressed connection’, whereby plates were connected at angles from the handle to the main instrument body, thus diagonally buttressing the handle. Whilst effective, this would be classed by LEGO® designers as an ‘illegal’ building technique [28].

A final meso-level divergence concerned the degree to which pupils designed their instruments with hand ergonomics in mind. Some made extensive efforts to do this, employing shaped pieces such as cylinder curves or boat pieces to ensure a comfortable grip. Others, including those drawing more explicitly on the step-by-step instructions tended to produce more ‘box-like’ shakes with angled edges, potentially more cumbersome in performance (e.g. compare figures 2 and 8 with figures 10 and 11).



Figure 10



Figure 12

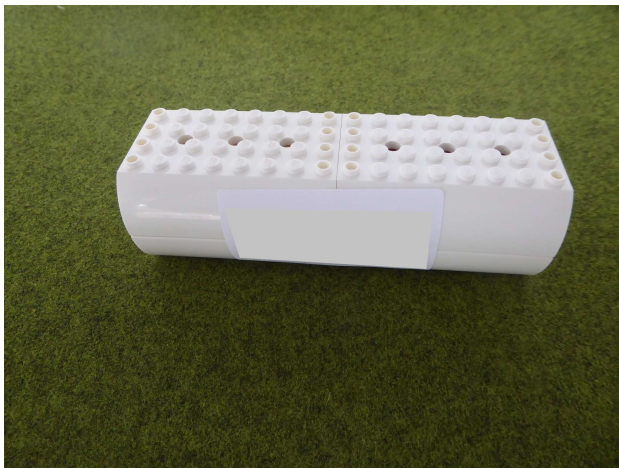


Figure 11

3.3 Micro-level diversity in pupils' instruments

Although termed 'micro' level categorisations within their taxonomy, we agree with Armitage et al. that it is at this level where much meaningful, expressive musical and decorative detail is to be found within musical instruments.

One way in which instruments varied at this level was in pupils' approach to colour coordination of LEGO® components. A minority had prioritised ensuring that as much of their instrument was a consistent colour, or featured regular patterns of colour. Others appeared less concerned, selecting components primarily for their technical merit. Given this division, it would be interesting to see how colour choices would be managed if longer versions of the same activity, where pupils could spend longer looking for desired components in the desired colour (compare figures 3, 8, 11 and 12 in their approach to colour).

There was also significant variation in the inclusion of cosmetic decoration on instruments. Some were purely functional, in that all components used related directly to the musical purpose of the instrument (as in figures 2, 3 and 8). Others, however, embraced playful, whimsical decoration schemes involving forest scenes, boat motifs and space rockets (e.g. figures 10, 12 and 13).



Figure 13

There was an interesting crossover in many cases here with the meso-level ergonomic considerations noted in 3.2.4, in that instrument shape might have been chosen for ergonomic or acoustic reasons but then developed decoratively on themes inspired by these shapes (e.g. figures 10 and 12). In one instance (not shared pictorially for data protection reasons), a pupil had arranged thin LEGO® plates to spell out their initials, potentially highlighting the personal attachment they had with their instrument – in line with arguments relating to the power of producing physical 'public entities' within constructionist-based learning [6].

4 Conclusions

Practical exploratory instrument design offers opportunities for pupils to engage with diverse disciplines in an integrated way, allowing them to find purposes aligned to their internal motivations and undertake engaged learning.

As educators concerned with providing an enriching musical and learning experience in its own right (see ‘Ethical Standards’) we offer reflections on the practicalities of the activities which might be helpful for similar work. Firstly, and in common with our previous fieldwork [1], focusing on musical performance at the end of the activity was an important means of motivating creative expression. Secondly, active monitoring was necessary to ensure pupils could locate appropriate components as efficiently as possible. Thirdly, pupils were accompanied to the workshops by school staff, and it was notable that the level of practical engagement in the task demonstrated by these staff acted as a further motivator to pupils, i.e. pupils whose staff member actively encouraged their instrument building tended to make more progress overall. Fourthly, the one-hour limit on the activity definitely influenced the instruments constructed. Accordingly, we have explored longer, multi-session activities in subsequent fieldwork [3].

The tripartite framework defined by Armitage et al. [26] enabled us to organise and analyse a sample of instruments produced from three perspectives: the types of instruments built, the choices pupils’ made about scaffolding, and the interaction of the two.

In relation to RQ1, the observable properties of the constructed instruments tended to fall into three categories (shakers, scrapers and drums) which all, to a greater or lesser extent showed influence from the instructional resources provided. In relation to RQ3, the instruction choice styles of ‘step-by-step’ and ‘launchpad’ tended to predominate, but the extent to which these were followed closely or used as the basis of creative extemporisation meant that it was not always clear to see the extent to which selected instructions had explicitly informed instrument designs. As we noted in the introduction, Ness and Farenga [12] characterised scripted VCPOs as having high affordance i.e. the outcomes are known and the instructions to reach them are clear. The macro-homogeneity observed in the instruments produced by the pupils who chose to use the step-by-step instructions is perhaps unsurprising.

To a lesser extent, and in relation to RQ2, we also observed the influence of instruction choice at the meso level, particularly in relation to the (albeit inconsistent) use of brick bond pattern, and components used for the sides of shaker and drum shells. It would be fair to say, though, that at this level, most pupils appeared to ‘depart’ from the instructions at some point to follow their own design, irrespective of the basic type of instructions chosen. So, for instance, they might have started constructing a shaker following the ‘step-by-step’ instructions but decided partway through to customise their design – potentially through an expression of personal creativity or

possibly due to the pragmatic availability of some components over others.

At the micro level, however, it was clear that most pupils had made largely personal choices in relation to decoration, apparently regarding these as areas where they could exert particular levels of creative personalisation.

In addition to instruction choice—but also relating to the general concept of scaffolding and bricolage in learning activities of this kind—we also observed the significance of the separately-provided ‘stocks’ of certain pieces as influencing many instrument designs as well.

The departure from the three types of instructions is encouraging when seen in the context of constructionist education. The bricolage that is at the heart of the approach is built on the idea of working with what is to hand and adapting it to the task. Pupils thus demonstrated not just that they could use the materials we had provided to suit their purposes, but that they could (equally importantly) discard them when they no longer suited that purpose.

Future work will include more formalised, quantitative assessments of the full set of instruments using several pre-existing scales of creative ideation [29, 30, 31]. More holistically (including both the digital [3] and acoustic aspects of the workshops), we will explore the potential for significant relationships between pupils’ choice of instructions, these formal construction assessments, and aspects of computational thinking relating to abstraction and decomposition included in the pre and post activity questionnaires [32].

Ethical Standards

We considered a range of ethical issues and these are discussed w.r.t the NIME Principles and Code of Practice on Ethical Research.

We aimed for the activities to be fully inclusive and to remove barriers to participation. Schools selected the pupils and we actively sought their advice on any adaptations needed to facilitate everyone’s participation on a fair and equitable basis.

As a plastic product, using LEGO® raises concerns about environmental impact. We reused as much of our existing material from previous workshops as possible, acquiring new items only where strictly necessary for the educational activities and safety.

The bricks used had been largely sourced second-hand to minimise new plastic acquisition and minimise costs. The activity described here does not require specialist LEGO® bricks and thus the second-hand market would be open to those wishing to do this for themselves. We have now prototyped a sustainable alternative based on recycled and recyclable materials.

Consent for personally-identifiable data processing was gathered as part of the wider participation consent activity that included gatekeeper consent for schools, staff and parental consent, and pupil

consent. Pupils were reminded that they could freely withdraw consent during the workshops (and indeed some did, electing not to complete questionnaires). Since video recording was in place for the whole room, participants who withdrew were still captured but their data is not used. This was made clear on the consent documentation for parents. The consent activities were carried out over several weeks with the support of schools (following their gatekeeper consent). Data capture and processing was planned in detail and with due regard to the various platforms used for capture and transfer (see [3] for more detail). Data was moved to the highly-secure institutional Data Safe Haven as soon as possible following the workshops. Data made publicly available is anonymised. We gave considerable thought to whether we could provide open datasets for sharing but ultimately judged this as infeasible because of the complexity of conveying how this would be achieved in participant consent and information documents. A Data Protection Impact Assessment (DPIA) was undertaken as part of our data protection due diligence, along with institutional registration, and the information governance training and detailed asset management requirements associated with use of the Data Safe Haven.

We feel that remuneration is inappropriate in this kind of situation: remunerating schools could result in pressure being placed on staff (and potentially students) to participate in workshops at the instigation of the gatekeeper. Remunerating staff accompanying the children as part of their normal duties seems inappropriate since they are undertaking their job in this respect and were not the focus of the research in these workshops (a staff workshop was also held, under separate consent – see [3]). Remunerating parents and children could be considered as coercive (because of the existing power dynamics between them, the school, and the researchers, and the fact that this was for them, a ‘school trip’ at the instigation of the school itself). We were mindful of the cost to schools in terms of transport and staff time and the implications were made clear in the gatekeeper documentation in advance. Schools that elected to participate covered these costs either internally or through external funding.

We undertook extensive risk assessment and mitigation covering physical risks (alleviating trip hazards and electrical safety risks), biological risks (minimising cross-contamination from bricks), emotional well-being (ensuring good signage to orient students in the building and signpost facilities), and safeguarding (through appropriate staff training, certification, and experience).

Finally, in aiming to achieve an equitable balance between the burdens and benefits of the research as experienced by the participants, we were careful to ensure that the workshops were designed to be intrinsically educationally and musically worthwhile and enjoyable for pupils and not simply opportunities to gather data to support our research goals. To give further value to the participants, we recorded the group performances and created slideshows of their instruments with the performance as soundtrack, and provided these to schools to use however they saw fit. This allowed pupils the opportunity to demonstrate the value of their

instruments (beyond their role in the workshops) as personally and socially important artefacts (linking to the concept of “social currency” of the objects created by students in the work of Eisenberg and Eisenberg [7]).

The project was grounded in the British Educational Research Association (BERA) 2018 ethics code and was reviewed and approved by the UCL IOE Research Ethics Committee (reference: REC1992) with a subsequent approval amendment also granted.

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