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A constructionist view of what it means to be digitally literate

Learning in 21st century classrooms

Abstract

Empowering Minds (EM) is a project that has deeply integrated technologically expressive materials—including robotics, presentation and programming software—into the educational practices of teachers at more than fifty primary schools across Ireland. In this paper, I present Empowering Minds as a model of constructionist learning and describe the learning principles which underpin the EM project. Learning experiences from two schools which focus on how key EM themes are represented in classroom work are also described. This paper concludes by highlighting the importance of a diverse community supporting learning informed by the learners' needs, interests and experiences, using technologically expressive materials as well as allowing adequate time for self-directed learning to develop.

KEY WORDS
Constructionism • learning environments • community • digital literacy • cultural connections • collaboration

In an increasingly globalised world which is driven by the needs of developing a competitive Knowledge economy we as educators need to ask the questions: what kind of future do we want to create for our students, what kind of people do we want to nurture and what values do we want to live by? Here, I present Empowering Minds (EM) as a model of constructionist learning which is inclusive and respects the inherent dignity of the individual. EM is a project that has deeply integrated technologically expressive materials—including robotics and presentation and programming software—into the educational practices of teachers at more than fifty primary schools across Ireland. The EM project demonstrates the importance of a diverse, supportive community and adequate time for self-directed learning to develop. In this paper, I describe the learning principles which underpin the EM project and outline examples of classroom learning experiences which focus on how key EM themes are represented in this classroom work.

1. Introduction

The Empowering Minds project (EM) is putting principles of Constructionism into practice within primary schools in Ireland. Students and teachers are learning side-by-side about robotics and computer programming, in creative contexts that invoke and depend as much on arts, history and culture as on science and engineering. EM classrooms are studio-style, constructive learning environments which are more akin to artists' studios than traditional classrooms. Each learner decides what projects to work on and therefore the contents of the learning and how to approach it. People from mixed generations and with multiple learning styles have access to the community, the materials and the concepts that the materials afford. Decision-making within the community is democratic. These methods emphasise dignity, equity and inclusion, promoting the values of control and ownership.

In this paper, I develop the themes of control and ownership that characterise the learning experiences within the EM project:

- Control, which addresses the power relationships as learners decide what projects to undertake. This negotiation and sharing of power is not only evident in the classroom between teachers and children, but is a characteristic shared by all who participate in the EM community. For example, teacher workshops and how the project organisational structures developed were negotiated between researchers and teachers. All teachers engage in significant hands-on immersive workshops for their own learning. However, when they bring the materials into their classrooms, it is on their own terms and with the support of the whole community.
- Ownership, which develops as children and teachers engage in their own projects, individually and collaboratively, and as each participating school contributes to the EM project overall. Just as individuals and collectives have rights to decide what projects to work on and how to approach them, they have responsibilities to the project community to meet agreed-upon deadlines, share resources and maintain the EM values.

As I discuss and develop the themes of control and ownership I also refer to and interweave other themes which are also an inherent part of the learning experiences of the EM project. These include the authentic nature of the learning experience which contributes to the high levels of engagement and motivation of the learners, community relations and the development of digital literacy. The paper is organised as follows. In section 2, the Empowering Minds project is introduced. Section 3 outlines examples of the classroom project work, focusing on the how key EM themes are represented in this classroom work and Section 4 presents some concluding remarks.

2. Introduction to the Empowering Minds Community

The EM project began in 1999 with a core group of four schools (urban-disadvantaged, suburban-advantaged, typical suburban and rural) and eight teachers. In the following year, the project expanded to twelve schools including more small rural schools and disadvantaged schools, as well as some single sex schools and children with special needs. The EM community has grown steadily since 2002 to include teachers and children from fifty schools with the more experienced teachers supporting the new teachers.

The EM project was founded with three core principles (Butler et al., 2000; Martin et al., 2000):

1. To encourage children and teachers to develop technological fluency with project-based learning.
2. To use technology as an integrating agent for learning.
3. To establish a new model of teacher professional development, in which teachers are centrally included in the process of pedagogical activity design.

The discussion that follows further develops the values of the EM project. The schools, from which I draw the examples in this paper, are small rural schools that became involved with the EM project in 2000. These schools have two to four teachers and a school population of between twenty five and seventy children.

Constructionist learning

The aims and principles of the Irish Revised Curriculum[1] (1999) reflect a socio-cultural approach to learning. The empiricist and rationalist traditions both view knowledge as an object, whether it is located inside or outside of the individual. In contrast, the Social Constructivists consider knowledge as a process with an intimate connection between knowledge and activity while also taking account of the contexts (social, historical and physical) of a learning situation. Consequently, knowledge is considered to be situated and distributed while learning is viewed as a social participatory process. Digital technologies do not have an independent existence and cannot be considered separately from the values that people bestow on them. So there is a consistency, explicit or implicit, between how people understand knowing and the nature of knowing and what technologies are valued and how they are used. The ways in which digital technologies may or may not be used reflect these understandings.

Taking cognisance of the connections outlined above, the principles of Constructionism underpin the design of the learning environment and how computational materials are used within the Irish primary school classrooms that are participating in the Empowering Minds (EM) project.

Constructionism, «the N word as opposed to the V word – shares constructivism's connotation of learning as 'building knowledge structures'» (Papert, 1991, p. 1). So rather than conceptualising learners as vessels into which knowledge must be instilled, Constructionism sees learners as active builders of their own knowledge and asserts that people learn with particular effectiveness when they are engaged in constructing personally meaningful artefacts. However, constructionists would argue that learning «happens especially felicitously in a context where the learner is consciously engaged in the construction of a public entity whether it's a sand castle on the beach or a theory of the universe» (Papert, 1991, p. 1). In our current digitised society, these artefacts can include designing and building computer programs, animations or robots. These artefacts are «objects to think with» (Papert, 1980, p. 12; Turkle, 1995) and a means by which others can become involved in the thinking process while the learner's thinking benefits from the multiple views and discussions. The tools and materials used influence the nature of the artefact and therefore the thinking. There is consequently an interrelatedness of a symbiotic nature that exists between learners, the materials they use and the constructed artefact that they create which becomes their «object to think with» (Papert, 1980, p. 12; Turkle, 1995). For this reason I have chosen the Celtic symbol of the trinity knot as its seamless design without any evident beginning or ending effectively captures this interrelatedness.

EM emphasises digital technologies both because they are prominent in contemporary culture, and therefore important from a skills-development perspective, but even more importantly because properties of computational materials characterise general phenomena that are worth knowing about. This includes ideas like variability and feedback which are fundamental to dynamic systems from thermostats to traffic patterns to weather systems to economic cycles to families and organisations. Learning about computation develops a basis for thinking about the world and how it works. However, sufficient time and the appropriate supportive environments also need to be cultivated in order that learners can construct their own understandings of what it is to learn and become actively involved in the learning process. Having the support of a community can also prove to be a very powerful learning environment as «other people are the greatest source of alternative views needed to stimulate new learning» (von Glasersfeld, 1989).

Expressive materials

EM emphasises the use of digital technologies because they are prominent in contemporary culture and therefore important from a skills-development perspective. However, this does not mean that we take a technocentric view of change in schools and learning. In contrast to the «information and communication technologies» (ICT) approach which bolsters the traditional transmissive mode of education we see computational materials as provoking challenges to existing values and beliefs about learning, not as

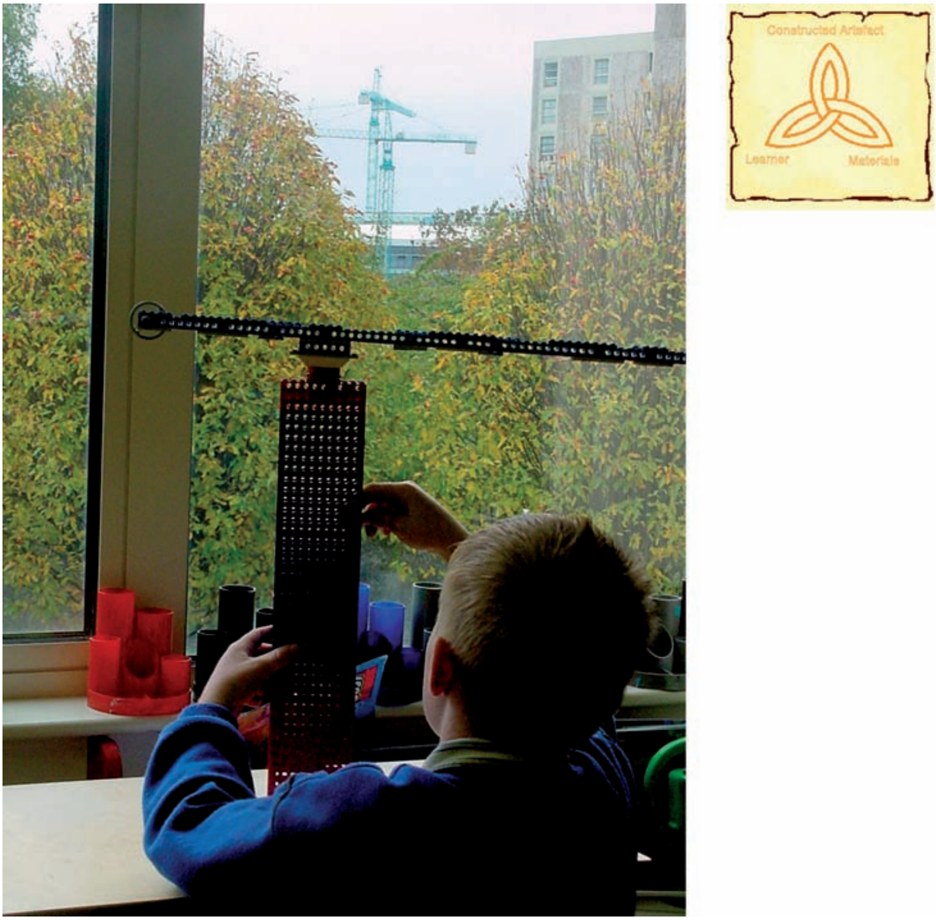
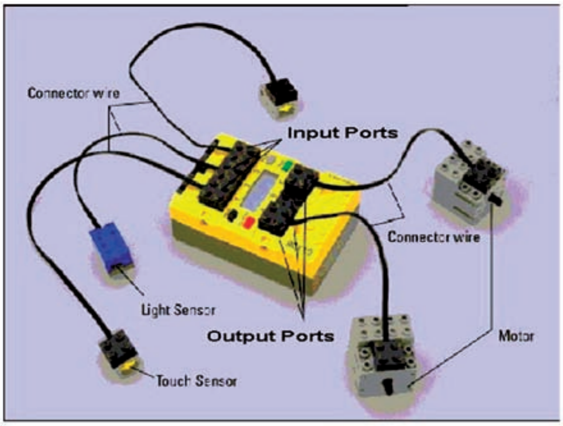


Figure 1: Constructionist Learning Model

tools to fit existing curricula. The malleable, protean nature of the materials we choose (i.e. LEGO Mindstorms and Logo Microworlds programming) demonstrate a wide range of behaviours and styles of presentation reflecting the creators' ideas through many manifestations. Thus these materials are well suited to enabling individual engagement, expression and learning. Consequently the computational materials used by the EM community are challenging, conversational and connective. They address personal needs and interests, they invite contemplation and negotiation and they support the development of personal relationships and ideas that transcend traditional subject boundaries. This transforms the teacher's role from that of a consumer of existing courses and curricula to that of an empowered, self-determined learner.



The commercially available LEGO Mindstorms product formed the core materials around which the EM project was developed. This robotic construction kit launched by the LEGO Group in 1998 is based on the Programmable Brick research at the MIT Media Lab (*http://www.media.mit.edu/*). The programmable brick was a derivative of the LEGO/ Logo work done in the mid-1980s by Seymour Papert, Mitchel Resnick, Stephen Ocko and Brian Silverman (Resnick & Ocko, 1990; Resnick, 1990). Situating the use of the materials within a story theme was key in creating a rich learning environment. This contributed to the immersive nature of the EM project as it provided a multidisciplinary focus to the many projects that were developed.

Atelier-style environments

The Constructionist approach is based on an intimate connection between knowledge and activity. Therefore the selection of specific building materials is an important starting point enabling Constructionist learning. Traditional classroom settings, however, are not conducive to the activity of building and to encouraging collaboration and the free exchange of ideas. Environments more familiar to artists, architects and craftspeople are better suited. In these environments, participants engage with complex, open-ended problems over a protracted length of time. They are encouraged to collaborate, they address a heterogeneity of issues and reflection is explicitly incorporated (Cavallo, 2000; Kuhn, 2001).

Reflecting these principles, the EM workshops have teachers working side-by-side with more experienced practitioners. The more experienced participants explain techniques and offer comments, interacting with the teachers «extensively, answering their questions, helping them solve problems and otherwise listening to their thoughts and concerns...This style of interaction was more as between peers than as between teacher and student; often the problem puzzling the [learners] was one we had not yet solved ourselves» (Martin, 1994, p. 65).

By engaging in challenging learning experiences themselves, the teachers find ways to understand their own learning which empowers them to develop alternative ways of structuring learning environments for their students. Through the course of the project we have seen strong and varied evidence that to «understand in a different way» increases potential for alternative actions (Gadamer, 1975; Dunne, 1992; Grundy, 1987; Butler, 2004).

As the teachers have transferred this way of working to the classrooms, the more experienced personnel have supported them heavily at first, through frequent classroom visits. Gradually the teachers and children have become comfortable with the computational materials and this new way of working has begun to grow as part of their culture.

In the next section of the paper, I present details of how the EM project unfolded in some of the small rural school classrooms.

3. Classroom Experiences – Cultural Connections

This classroom example illustrates how a traditional curriculum can be approached from a 21st century perspective using expressive computational materials in an inter-disciplinary way while taking cognisance of the needs, interests and experiences of the learners. In keeping with the EM community's narrative theme [Martin et al., 2000], the teacher and child collaborators in this example chose to work with the «Díarmaid agus Gráinne» epic in Irish folklore[2]. This is a wonderfully varied story of love, adventure, action, pursuit and excitement, enjoyed by male and female, young and old alike. As they created their own version of this ancient Irish epic they were engaged in a variety of learning activities ranging from exploring narrative, working with building materials and problem-solving to designing, collaborating as a team and working with sensors and programming. This classroom example demonstrates effectively that these children and their teachers were active makers of their own meanings, empowered to use and shape the world with these «convivial tools», rather than be shaped by them (Illich, 1974).

The children and their teacher chose two scenes to construct from the story, one using LEGO Mindstorms materials with the programmable bricks and the other using clay models and the Microworlds or iMovie programming environment to create an animation. The episode I have drawn upon here is the work they engaged with using the LEGO MindStorms materials. Conor, the teacher kept a reflective diary[3] during the development of the project constructions. The account details the range of materials used, the types of problems that emerged, the modifications to the story resulting from negotiations with materials and Conor's appeals to the larger EM group for help. It also demonstrates how the project facilitated the integration of many aspects of curriculum, including heritage and culture, history, science and engineering, problem solving, writing, arts and crafts, design and construction, communication and collaboration and language development.

Díarmaid's escape from the stockade

The following is a student's description of the scene that they had selected to illustrate from the epic as presented by the teacher in his journal:

> The Lego scene we have chosen describes Díarmaid's escape from a fort he has built in the middle of a forest. He has built a stockade with seven doors in it around the fort. His enemy Fionn surrounds the stockade, so Díarmaid cannot escape. In our scene we want Díarmaid to walk around to each of the seven doors, pause at each one to find if there is a means of escape. At the seventh door he realises that Fionn is outside it with lots of soldiers. So Díarmaid decides to make his escape here. He actually pole-vaults out over the stockade using his spear, and lands well beyond the bank of soldiers surrounding the stockade. We want to get a good model of Díarmaid built to walk around to each door and stop, get each door to open, and finally at the seventh door get Díarmaid to escape over the stockade (Conor's diary, Feb. 2003).

In order to enact this scene Díarmaid must be able to walk around the stockade and pole-vault out. The children's initial idea was to use a magnet to move him around and to build a crane to lift him, in order to give the impression that he was pole-vaulting out over the walls of the stockade.

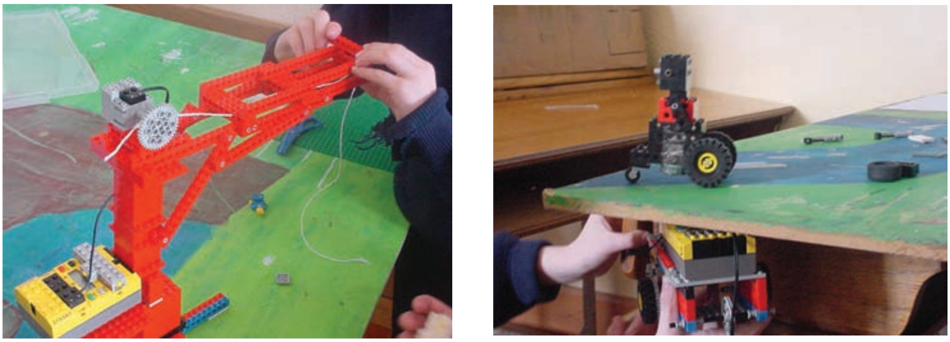
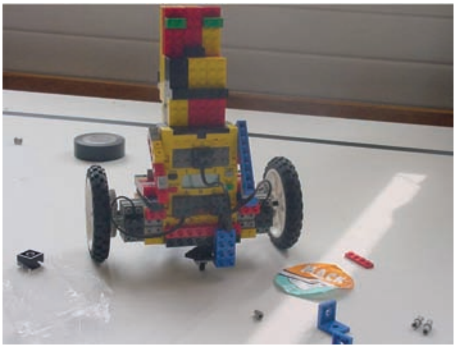


Figure 2: Building a crane to lift Diarmuid and testing the magnets to move him.

However, after many different design attempts, they discovered that their magnet idea would not work. The board they were using as the base was too thick, and even varying thicknesses of board did not solve the problem. The children then decided to embed a programmable brick within the Díarmaid model. This meant that the model was now autonomous and it could be programmed to move around as required. Previously, the children had built projects using light sensors and programmed them to follow a black line which determined the path of an autonomous robot. In their new plan for Díarmaid, he would follow a black line as he moved from door to door looking for a way out of the stockade (Figure 3).



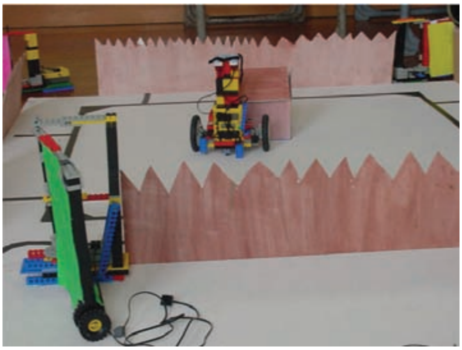


Figure 3: Díarmaid with programmable brick (left); Díarmaid in the stockade

However, this new design caused other problems. Díarmaid was now very heavy, and despite several different attempts at designing an appropriate crane, the children could not construct one capable of launching the new heavier Díarmaid out of the stockade. Now they had the problem of how Díarmaid could pole-vault away from his enemy Fionn and the awaiting army.

Unable to construct a scenario that remained true to the original storyline, the children and teacher discussed at length what to do. They decided to program Díarmaid to approach each door looking for Fionn, as outlined in the original story. Then he could send a signal to the door in order to open it and see what was behind it. If Fionn was waiting and escape was not possible he would move on and try each door in turn. This solution meant that Díarmaid needed a new program each time he moved to a new door. The original story had seven exits to the stockade. However, the brick can only store five programs at a time. After lengthy discussions and considering numerous possibilities, they decided to change the story from seven to five doors. However, as Conor notes:

> «We still have a problem with getting the Díarmaid lifted out over the wall… so we'll have to use our imaginations to create a 'twist' in the story, to get him to escape in a different way.» (Conor's Diary, March 2003).

They decided that, because of their crane-building difficulties, they would take poetic license and change Díarmaid's escape strategy. He would no longer pole-vault, but would trick Fionn by faking an exit from door one and escaping through door five. Once they had made the story their own, they now had to programme their models to reflect the changes they had decided upon. The main programming elements involved getting Díarmaid to follow a black line, sending a message to each door's programmable brick, writing the programme for each door to open and ensuring that Fionn would move from gate five to gate one at the right time.

This learning story from the classroom demonstrates how the teacher and children have acquired a high level of digital fluency as they comfortably discuss and consider critically the trade-offs between the structure of the story and the computational materials they are using. Encouraged to explore and willing to spend time exploring, they tried out many different designs for their models using the computational materials. They were not constrained by the parameters of the story as they realised the limitations of the materials they were working with. This confidence in decision-making indicates deep understanding of the technology and the spirit of the project, as well as a strong sense of ownership and control.

4. Classroom Experiences – Community Connections

This classroom example illustrates how children's learning can become more meaningful when it is informed by their local identity and then transformed by building cross-generational links and strong connections with their local community as a result of trying to solve an authentic problem.

The initial spark of the idea for this project was inspired as a result of an observation of the demographics of the local community. It happened during a conversation in class when one young child observed: «There seems to be lots of old ladies but very few old men in our local area.» Puzzled by this observation the teacher, Kathleen encouraged the children to enquire at home that evening if this observation was in fact true and if so what could be contributing to this. Upon investigation it emerged that a contributing factor to the shortage of «old men» was that there had been a coalmine in the area. Many of the miners acquired a condition called «miner's lung» and died . Encouraged by the children's natural curiosity to explore the connection between the existence of a coalmine in their locality over fifty years ago and the fact that many of them had no grandfathers, the teacher facilitated a large scale investigation about coalmining. The children consequently investigated how coal is formed, where coal mines are located, how coal is used today and in the past and read stories about life in the mines and so on.

Besides the project being a wonderful vehicle for developing cross-curricular linkage it also fostered strong cross-generational links between the school and the community as the children tried to construct a working model of the coalmine that had existed in their locality. The children's investigations sparked off much home discussion about the life and times of relatives who had worked underground. The children then began to use their information to write historical reports, fictional stories and poetry and to build their working model using the computational materials.

> «Groups of children were assigned different sections of the mine and asked to use their Lego to build a model of a mine based on the stories and information collected from their families and their research. Adult help was enlisted to create a timber cross-section of a mine tunnel so that

> ‘coal’ could be ‘mined’ and brought to the surface where it could then be processed by the children’s machines» (Kathleen’s project report).

Kathleen’s enthusiasm for the project was infectious and her family too were intrigued by the children’s investigations and followed the project’s development with interest. The timber frame for the coalmine was actually constructed by Kathleen’s retired father with input from the children about the dimensions they required. In tandem with the ongoing dialogue about the project that the children were engaged in at home the various groups of builders also had to continually collaborate with each other as the building of each section of the coalmine was interrelated. The group building the «bogies» which brought the coal to the surface had to liaise with the group that was assigned the task of getting the coal from the bogies up into the sorting «hoppers». This «conveyor belt group» also needed to liaise with the «hopper building group» about the height of the proposed «hoppers» as the amount of chain available was limited and this had a bearing on the angle of elevation on the conveyor belt itself.

> «Two groups of girls undertook the job of building the hoppers to sort the coal. The building of towers underneath which small trains could travel was initially difficult and as the week wore on we began to wonder if two stable structures would ever emerge. The two groups eventually agreed on a design and then the negotiations over height restrictions with the conveyor builders and the coal removal group became rather involved. These two groups now had to devise a method whereby the coal could be contained in this tower and then permitted to fall through to the waiting truck. The groups eventually adapted the vertical sliding door to create a sliding trap door in the base of each tower» (Kathleen’s project report).

The above extract from the teacher’s project report clearly demonstrates the intricacies of the design process and how each group had to closely negotiate and collaborate in order to build a complex working model of the coalmine. Their models became their «object to think with» (Papert, 1980, p. 12; Turkle, 1995) as they solved each problem as it arose. The children were motivated to continue building their models despite all their setbacks and problems as they had a personal connection with the problems they were trying to solve. Each of their models went through a series of iterative designs as they refined their ideas with feedback from the other groups. As Resnick and Ocko note: «In this way, students get a sense of the way in which real designers go about their work, as part of a community of designers» (Resnick & Ocko, 1991, p. 6).

The authenticity of the overall building process was monitored regularly by the grandfather of one of the children who had worked in the local mine during his youth (Figure 4). This ongoing cross-generational collaboration further strengthened the children’s personal connections with the models they were constructing and the problems they had to solve in order to incorporate the details required to construct an authentic model of the disused local coalmine.


Figure 4: Cross-generational learning

> «Mr. Kealy told the children of his experiences as an adolescent working in the mine. He used their own model to explain his working day and to further describe the machines that they had built. Their initial models were built without reference to pictures of working models so it was interesting to hear how they concurred with or deviated from actual designs. He described how in one of the mines in which he worked the men were lowered down to the workface in a cage. The air-shaft was altered the next day to show a miner being lowered with his pickaxe into the mine. He also explained how when the coal came from the mine it had to be crushed. He was carefully quizzed on what a crusher might look like and the following morning a crusher was created and placed between the tunnel entrance and the conveyor belt (Figure 5). It was felt by the children that the coal would have to be swept along to reach the conveyor belt and so a mechanical sweeper was added to push the coal from underneath the crusher. This was connected to the RCX [programmable brick] operating the hopper trapdoors as the children felt that the same programme would work» (Kathleen's project report).

Figure 5: Crusher on the right with a conveyor belt taking the coal over to the main conveyor belt where it is being taken up to the sorting towers. The programmable bricks have been enclosed in a different coloured casing for easy identification by the different groups.

On one of «the grandfather's» visits when the children were demonstrating the pulley system they had designed to bring the bogies to the surface he remarked that the original mine had in fact a double rather than a single pulley system. The children immediately wanted to reconstruct their pulley system to reflect this fact. However, this desire to reproduce an authentic working model caused a major problem for the children when they tried to reproduce a double pulley system for bringing the «bogies» laden with coal to the surface. After many attempts without success, «advice was sought from family, neighbours and the wider community …..» (Kathleen's project report). Such was their engagement with this problem that the children and teacher voluntarily worked for many hours after school and at weekends. Finally, after much input from a range of people who called to work in the school with the children

> «the pulley problem was solved. Two strings were used instead of one continuous string and a weight attached to counteract the problem of slackening thread as two different circumferences of thread simultaneously unrolled from a single axle» (Kathleen's project report).

Further refinements were made to the model of the coalmine as a result of the children's visit to a local disused mine.

> «Following a meeting with Mr. Seamus Walsh, an expert on the history of mining in Castlecomer the children were taken to see a local mine. They were accompanied on this trip by Mr. Kealy, Mr. Walsh and a number of parents. They were thrilled to see the bogies still standing on their tracks, miner's hats and boots, pulley wheels and gears. They were to discover that they were a great deal heavier than their own building materials. They accompanied Mr. Walsh into the mouth of the tunnel and were not impressed with the damp and the smell. They observed the piping to remove the water from the tunnels and this was added to their model as soon as we returned to school. Following their observations of the belts and crushers all the group efforts were combined to create the seamless effect of the coal arriving at the mouth of the mine to be crushed and then sorted for sale» (Kathleen's project report).

This project is an example of how learners in the EM community are actively determining their own goals rather than functioning passively in the classroom. This learning by doing is much more meaningful than rote learning or reading about something at second hand. These children were driven by their own sense of wonder, had ownership of their learning agenda and actively constructed knowledge for themselves. This pursuit of personally set learning goals concurs with the research undertaken by Jonassen et al. who note, «when students own the knowledge rather than the teacher or the textbook, they become committed to building knowledge rather than merely receiving and reprocessing it» (Jonassen et al., 1999, p. 118).

5. Conclusions

The classroom experiences described in this paper provide richly textured concrete examples of Constructionism in practice. Illustrated with extracts from the teachers' diaries they describe the development of the projects these teachers engaged in with the children and outline the trade-offs made between the computational materials used and the learning goals set by themselves and the children. What is apparent is the level of digital fluency which developed considerably as a result of engagement with the EM community. The children and their teachers also display a confidence and an ability to make independent decisions as they discuss what is appropriate to do considering the limitations of the materials (e.g. changing the events of the story as Díarmaid tries to escape the stockade). Encouraged to explore, they do not accept materials as given, to be used in a rote manner, but can decide how to use them for their own purposes. However, in keeping with the constructionist spirit of the project their constructions also become «objects to think with» and they are willing to engage in a dialogue with others and adapt their models as a consequence of the feedback they receive (e.g. the changes which were made to the coalmine models based on their efforts to maintain the authenticity of their models to the original construction which had the double pulley system). This confidence in decision-making indicates deep understanding of the technology and the constructionist nature of the project, as well as strong senses of control and ownership.

Considering the demands of the emerging globalised, digital society of the 21st century I am in agreement with Beacker when he states that:

> «… we must enable students to attack problems of greater complexity than teachers have traditionally addressed through a fixed curricula, memorization of facts and an emphasis on isolated skills that are not applied to real-world problems» (Beacker, 1992, p. 10).

Papert (1980) noted that «through the construction of educationally powerful computational environments», an alternative learning environment to the traditional instructionist approach could be developed. The EM learning environment from which these classroom examples are drawn is one model that is providing an alternative to traditional classroom settings for learners to engage in meaningful learning. The constructive projects described in this paper which were developed with expressive materials in Atelier-style learning environments provide evidence of learning about self and computational ideas beyond what any test could measure, provoking challenges to the epistemological foundations of traditional schools and curricula. Rather than perpetuating models of everyone learning the same fixed knowledge in the same way, the protean quality of digital materials enables individual exploration and expression as learners engage ideas that span disciplines.

Within the EM learning environments described in this paper the world of the learner is respected and the teachers involved have designed activities that are driven by the children's interests which, they believe, make them inherently authentic. The constructed models are based on the reality of the children's experiences. In grounding the activities in a real-world context, the learners are being engaged and stimulated to construct knowledge for themselves, in meaningful ways. Articulating an intention is essential for meaningful learning (Jonassen, et al. 1999) and, in the EM learning environment, learners are encouraged to articulate their learning goals, the decisions they make, the strategies that they use and the answers that they find. When learners articulate what they have learned and reflect on the process, they understand more and are better able to use the knowledge they have constructed in new situations (Grabe & Grabe, 1998). Dunlop and Grabinger (1996) argue that when students work and articulate together, students go beyond just thinking and reflecting on what they have learned. They must confront the ideas of others, whilst voicing and defending their own beliefs and ideas.

> Articulation means that students must present their ideas and perspectives, solutions and products to others for reflection, review, criticism and use, (Dunlop & Grabinger, 1996, p. 77).

In the constructionist environments that have developed over time in these schools, a learning community has emerged which comprises teachers, mainstream mixed-aged pupils and a range of people from their local community, working collaboratively. The schools have moved from a situation where they were isolated with little communication with others to being active members of a meaningful learning community.

However, implementing a constructionist approach is not easy and developing a constructionist-learning environment takes time. It is critically important to have a supportive learning community with a diverse range of backgrounds and which addresses each individual's needs, interests and experiences. Provocative, engaging and challenging computational materials are also needed and most importantly there must be adequate time to allow self-directed learning to develop and changes to take place.

Developing a constructionist learning environment also requires «buy-in» from teachers, students and the administrative staff in the school. Teachers and students are challenged to assume new roles with different beliefs and values than they have traditionally pursued. Teachers have to develop skills to support the students' thinking, to set challenging learning experiences and to create a learning environment which encourages student autonomy to explore and test out new ideas, to set learning goals and take responsibility for attaining these goals and, in time, to become self-determined learners. Most importantly, the project models how working with digital technologies can promote the values we want to live by, nurture the kind of people society needs and develop the very future we want to create. The implications of adopting a constructionist approach imply risks for teachers, students and administrators, but the enthusiasm and excitement generated by the teachers and students as they construct their own understandings and engage in using the materials, is more than sufficient reward for taking these risks.

Notes

1 http://82.195.132.34/index.asp?locID=2&docID=-1

2 http://timelessmyths.com/celtic/ossian.html#Pursuit

3 http://empoweringminds.spd.dcu.ie/discussions/reflections/one-reflection?id=35

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