Design and Project Approaches in Computing Education

In a previous chapter we looked at concrete and abstract approaches to computing educations and learning to code. One of the tactics to make learning concrete is to get your learners to design and complete computing projects. The pedagogies and frameworks that support the creative processes involved in undertaking computing projects in an educational setting have a tremendous potential to deliver transformative learning experiences.

In this chapter we explore some of the strategies that can be used to support the delivery of design and project based approaches. To start with I focus on the value of creative communities before tackling the areas of design-based approaches to computing projects and take a broad look at some of the benefits and processes of project-based learning. This chapter then turns to look at some tactics for overcoming limitations in what you can achieve in the classroom.

## The Power of Communities

A project based approach to learning coding and computing can be something that emerges from the home environment. For example enthusiastic older family members may take young people to Maker Fairs or engage in other community coding activities. Family members may buy creative computing kits or access resources such as YouTube videos or via online forums for specialist subjects like robotics or game making.

However, access to this kind of computer enthusiast community is not available to all young people. The following initiative aim to address this by providing entry points to community orientated coding.

**Code Clubs** are designed for out of hours school clubs run by teachers and provide inspiration and resources to help build a lunch-time or after school community. A large number of high quality, colourful and attractive resources are supplied free of charge on their website. It was originally an independent organisation which is now part of Raspberry Pi Foundation. https://projects.raspberrypi.org/en/codeclub

**Coder Dojos** are monthly events run by volunteers often at the weekend. They often focus on creative, engaging computing. I have volunteered at some events and been impressed at the dedication and inventiveness of the other volunteers. While some attending the event will use existing resources to support Scratch, others will try out new and experimental work around hacking Minecraft, creating games with code engines and new technologies of physical computing. Often volunteers use their own children who act as guinea pigs testing activities out on their family before bringing it to a Coder Dojo. https://coderdojo.com/

**The Coolest Project** is another project taken on the Raspberry Pi Foundation. It addresses one issue with monthly Coder Dojos. There is often a difficulty in maintaining project interest from one month to the next at Coder Dojos. Ongoing projects allow students to tackle problems in a radically different way to much classroom teaching. As well as a greater amount of time dedicated to hands-on coding and physical computing challenges projects provide opportunities to engage in authentic coding practices. These include: designing for real users, collaboration with other students, project planning, debugging faulty code and repeated revisions to fine tune the desired result. https://online.coolestprojects.org/

Coder Dojos are family-focused and thus less easy for teachers to engage with. But they are a good source of inspiration for teachers looking for creative project ideas for their classroom. However, both Code Clubs and the Coolest Project are suitable to run inside schools by computing teachers. Running lunchtime or after-school projects, while not reaching all pupils, can be a great way to showcase the engaging and creative nature of hobbyist computing projects.

### Communities in Educational Theory

The power of communities has been highlighted by academics as part of what is known as the “social turn” in educational. This is a turn away from more individualised ways of learning concentrating of efficient transfer of knowledge from the teacher to the pupil. Instead the focus is on how learning happens through participation in communities and culture, socio-cultural approach.

Community in this educational context provides support in creative process as well as motivating initial participation. Barbara Rogoff (1994), a key researcher in the socio-cultural approaches to education, has described an educational process called *Communities of Learners* - http://tiny.cc/communityoflearners. Rogoff sees this approach as radically different from both instruction based models of learning and pure discovery learning. Participants have different levels of expertise and varied roles in a learning system working towards an authentic goal. Rogoff notes that observing this kind of learning can be confusing to teachers and parents used to more instruction-based approaches. Such a learning community in full swing can seem chaotic. This seems like chaos because complex and productive learning is happening in ways that we, as teachers, may be unused to. This chapter helps unpick some of these practices and explore ways that educators have structured their learning environments to take advantage of this powerful approach.

### ACTIVITY - APPLYING A COMMUNITY APPROACH IN THE CLASSROOM

Are you making the most of the power of communities in your classroom. Before you start your next unit of work you can ask you self some of the following questions.

* Are there regular opportunities for learners to work together during your unit of work? How often will students give and receive peer feedback?
* Are there examples of similar work from other students available for your students to examine and perhaps repurpose?
* Can you draw on the roles or identities that students have adopted in their previous school or home activities? Are they able to reflect on the specifics of those roles to contribute to the effectiveness of their engagement in teamwork?
* Can you help your learners make connections between their computing activities and other professional or enthusiast communities outside of the classroom?

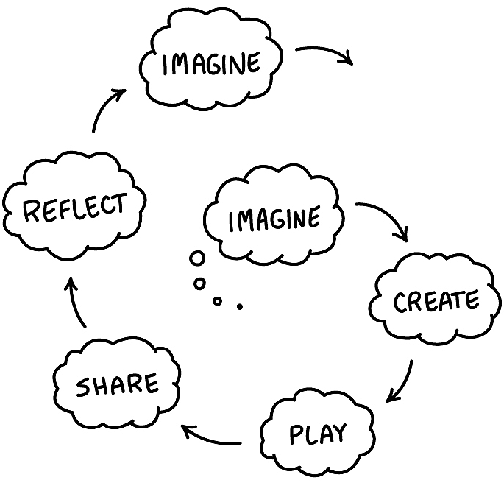
## Design-based Approaches in Computing Education

Designing as a discipline involves both a community of producers and users. Design-based approaches have been adopted widely in software production, creative industries and wider business contexts. These design principles and practices are also relevant to education. If you are an educator the experience of seeing students motivated by producing something for a real audience may be familiar. Design projects allow students to develop important 21st Century Skills like problem solving and communication, and to creatively respond to real life contexts. In the following sections I will explore the design-based approaches of iteration, design patterns and the use-modify-create model.

### Iterative Design Techniques

Iterative design involves coming back to reflect on the initial outcomes of creative goals and revising them based on results. In simple terms the process involves: goal setting, creating quick prototypes, user testing and evaluation, revision and reflection. The process is iterative in that testing and revision of the prototype design can be repeated until the desired result is achieved. Iteration is also a key part of a more general scientific method of testing an idea and then revising that idea based on your analysis of results. The idea of a repeated (iterative) spiral approach which both deepens understanding and improves the end results is popular both in education and industry. In software and design industries it is often referred to as Design Thinking and Agile approaches. In education this approach is referred to in concepts like the spiral curriculum and promoting student mastery.

Researchers involved in the Scratch project at MIT illustrate an approach to design-based education through a creative cycle. The five circular stages are; Imagine, Create, Play, Share, Reflect and returning to Imagine once more. The model encourages both parents and teachers to create a supportive environment for creativity. See http://tiny.cc/creativespiral.

 *creative spiral* *Diagram of five circular stages; Imagine - Create - Play - Share - Reflect - Imagine - NEEDS REPRODUCING OR REMOVAL*

Resnick (2012) describes the foundations of the design-based approaches in education as; engaging in design activities, exploring personally meaningful topics, collaborating with others, and deepening understanding through reflection. The key reason to adopt these principles is to increase engagement with sustained participation in computing projects from a broad range of learners. One of the sources for sustained engagement is when, as part of the iterative process, learners are able to test and then revise their creation or experiment based on their own evaluation. Another factor is the importance of a community in the design process, as a real audience for creations, as a source of inspiration and as peer evaluators in the testing process.

It is vital to act on an increasing understanding of diversity of student abilities and the importance of closing an achievement gap between the higher and lower achieving students. The above principles is in line with key inclusive practices contained in Universal Design for Learning (UDL) including: allowing students to demonstrate their knowledge in a multitude of ways and of allowing students to follow their own interests and motivations (Capp, 2017). As teachers we have a responsibility to evaluate how effective these methods are for our learners with diverse educational needs.

### Worked Examples and Design Patterns as Educational Tools

Design patterns are most commonly used for computing students at higher education to teach object oriented computing but they are also useful for all levels of learners. Design patterns are solutions to problems or common scenarios in design areas. Design patterns are rooted in real-life incidences of problems that are often solved in a particular way. They are concretes example of coding principles in context. Design patterns can help the development of coding communities if more experiences coders take the time to document the patterns they use in an accessible way for novice coders.

There are similarities between design patterns and a technique called *worked examples*. The National Center for Computing Education (NCCE) promote worked examples as a classroom activity. They have created a Quick Read document for teachers on worked examples here - http://tiny.cc/worked-examples. Both worked examples and design patterns act as a way to demonstrate underlying principles in practice. For both approaches showing working code used in a particular context helps students to analyse what makes it work and why it is a suitable solution.

For educators the use of design patterns and worked examples can help support learners develop coding proficiency by providing scaffolding and modelling good design decisions. However, one of the challenges for teachers of using worked examples and design patterns is how to integrate them into student-led design challenges. You may be able to create a menu of printed or online patterns or examples that students can draw on as needed. Perhaps particularly common examples can be modelled to the whole class when it is clear that many students will benefit from that approach.

### The Use-Modify-Create model

The iterative design cycle the Use-Modify-Create (UMC) model is designed both to limit learner anxiety for novice coders and to scaffold the acquisition of coding and computational thinking concepts (Lee et al., 2011).

**Use:** In the *Use* stage, coders build a familiarity with coding interfaces and code structures and syntax through scaffolded approaches.

**Modify:** In the *Modify* stage learners progress to working on real projects created by others. Learners deepen their knowledge of coding structures and practices by altering existing projects and templates to suit their own aims.

**Create:** Progressing to the *Create* stage - is not an immediate process. After novices become more familiar with patterns of code design in use in the modify stage, they can progress to replicate such patterns in other code that they create from scratch.

A study involving five hundred 9 to 14 year-olds found that the UMC approach can balance a structured approach with more student-led exploration (Franklin et al., 2020). The researchers also found that the students enjoyed UMC approach as they had more choice and agency in the process. This is supported by other research which compared a UMC with a starting-from-scratch approach and found higher student engagement for those in the UMC group (Lytle et al., 2019). The researchers found that because students had more time to play around with code, they were able to add their own personal touches and that that ownership over the code sustained their continued engagement.

Kafai and Burke (2013) argue that a shift from writing programs from scratch to modifying and remixing them is inline with socio-cultural teaching approaches. They coin the term computational participation to reflect this change of focus. They also note that such remixing is helped by online coding communities that may be either semi-professional or come from more of a DIY or youth culture perspective. They encourage educators to avoid focusing solely on technical possibilities of coding environments but to also embrace the potential of associated coding communities.

However, the researchers also acknowledge the challenges of teachers embracing remixing practices, which look a lot like copying, and participation in online communities which require learners to concurrently build both technical and participatory skills. The following case study examines ways in which the online Scratch community is facilitating design-based learning. It makes a strong case for the value of these approaches and asks how some of these benefits can be made more inclusive for learners who would struggle to take part in such a community independently.

### CASE STUDY - How the Online Scratch Community supports Design-based Learning

Scratch (available at https://scratch.mit.edu/) is educational software which uses block based coding approach and a set of tools to develop and integrate audio and graphical assets to help the creation of multimedia coding projects. Scratch as a project excels in its user community. There are over 75 million users of the site who have created 80 million projects. Activity increased during COVID restrictions in 2020 and 2021 with over 20 million user comments in the month of March 2021 alone. The online community allows young creators to connect with others to share and get feedback on their work. Such community interaction can help learners sustain the kind of repeated effort that builds a mastery which shows itself as a fluency in the design and coding process. Here are some of they key features of the online Scratch community with tips to integrate these into your computing teaching.

**High diversity of creations:** The process of keeping such a large community up and running and safe for young people requires a lot of resources. However, the effort is justified as it has become an extremely rich source of inspiration for young creators. A simple search of the site for projects like games, creative greeting cards, storytelling projects and pretty much any digital product you can imagine will yield multitude of results. As teachers we can draw on this resource to demonstrate diverse creation and encourage our learners to adapt existing work based on their one interests.

**Diverse ways to participate:** There is a great variety of forms of engagement with the online community. Your students may just play others’ games, or just comment. They may use it to create their own projects but not engage in the more social elements of the creative process. They may like a smaller section of the community become extremely active in creating and collaborating with others on shared projects.

**Encouraging project iteration:** Scratch encourages remixing of others projects and makes it easy to create different versions of your own projects. This encourages sharing drafts for feedback via peer comments which have been shown to encourage the development of new features. Teachers may need to balance the more disruptive possibilities in the classroom this feature offers with the clear benefits to build student autonomy and reflection.

**Supportive and authentic audience of fellow creators:** Due to high numbers involved in this community there is a good chance of finding peers who are also interested in specific subject matter and proficient in coding techniques. Collaboration between community users as peers is motivated by these shared interests. The potential and depth of collaboration of this community can be impressive. Roque and colleagues (2016) have described this in detail (see - http://tiny.cc/scratch-community). The researchers describe how individuals find each other and group together by forming *studios* and then recruiting other members to work on joint projects. This is sophisticated behaviour which mimics real production processes. It is carried out by young people with a high degree of independence. Researchers also note that such collaborative production is only carried out by a very small proportion of the online creators.

Teachers should be aware of a key challenge identified by the researchers, namely how to replicate the benefits of collaborative community activity for young people who have less experience or confidence. In response Roque (2016) went on to develop related programmes which including online project exhibitions, competitions and off-line family-based programmes to engage under-represented groups - (http://familycreativelearning.org). As educators, we can take inspiration from this process of replicating the highly engaged, organic feedback and support of the chaotic online community into a more offline and structured design-based environment. The second half of this chapter addresses ways you may be able to rise to this challenge using project-based approaches.

### ACTIVITY - USING DESIGN-BASED APPROACHES IN THE CLASSROOM

You can ask you self the following questions to try to check if you can use some of the beneficial aspects of design-based approaches in your classroom.

* Are learners able to explore exemplar materials to inspire and shape their creative ideas?
* As they plan, are learners able to think about and articulate the perspective of the real or imagined users of the designed projects?
* Are learners helped to come up with ideas through ideation techniques that scaffold the creative process?

**Follow-up Resources:** I have created several online courses which explore hands on ways to use design thinking in education and community work. https://rise.mmu.ac.uk/category/enterprise/design-thinking/ - At the time of publishing resources are open to all you just need to log in to access the courses.

## Projects and Project Based Learning

Project-based learning is a wide set of approaches that seeks to facilitate learning though undertaking practical projects. Students often complete project in groups. Students develop target knowledge and skills in the context of a real or simulated problem that they must solve. Project-based learning (PBL) is one of the 12 teach computing principles advocated by NCCE. In the next section I cover the characteristics and potential of PBL.

Computing education is an excellent vehicle for a project-based approach to learning. The nature of digital making and the many flavours that are available provide a wide-range of choices of project outputs. Websites, games, wearable technology, phone apps, robotics and other physical computing projects are all familiar products. Researchers Blumenfeld and colleagues (1991) argue that school disengagement is caused by work that bores students. They found that project work incorporating learner choice and involving real outputs is more motivating and can sustain student engagement. They also concede that implementing PBL in classrooms is not straightforward. I cover barriers to PBL and ways to overcome them in the final part of this chapter.

Academics have worked with expert practitioners to create PBL frameworks to help teachers to plan and deliver projects, and also to recognise the complexity of some of the learning that takes place. The following outline of PBL elements is a synthesis of several of these frameworks with additional commentary on how this may apply to computing projects.

**Challenge:** The focus of the project should be a relatable problem or question that is does not have one straightforward solution. Software and electronics projects fit this brief are thus very suitable candidates.

**Authenticity:** Real-life relevance of projects helps engage student as they make connections to their interests and communities. As mentioned in the section above, many forms of coding projects from phone apps, websites and games meet this need well.

**Sustained and Collaborative Work:** Adequate time must be allocated. Students should work together and be given the chance to revise projects. This is perhaps one of the greatest challenges to delivering computing projects in a secondary school setting.

**Public Project:** The creation of a shareable, public object helps learners focus and to design for others. It can also act as a focus for discussion within the classroom. Sharing of computing projects within the classroom could be supplemented by presentation on the web to a wider audience.

**Student Voice and Choice** Giving students choice over the focus of their project increases their engagement and participation in open discussions about project direction builds student autonomy. The high level saturation of digital products into the experience of many young people’s day-to-day lives can help shape student’s interests.

**Reflection and Critique** Self-reflection may be informal at times but also guided by class processes like learning journals. It can also involve peer feedback or input beyond the classroom to bring authentic perspectives. Reflection could also happen in a digital form via an online journal or templated digital document.

### Stages and Resources to Support PBL in Computing Classrooms

PBL is aligned with design-based approaches and UDL in many ways. They all require or benefit from a collaborative community and a real or imagined audience which learners create a public product for. Community-driven participation, motivation and feedback underpin the socio-cultural nature of the student’s learning.

One critique of project-based learning, especially where it involves student experimentation and student discovery, is that it can is chaotic and more challenging to communicate high-level concepts. It also requires skills, support and planning that are very different from traditional teaching and therefore may be difficult for teaching staff to implement. For example, practitioners must build their ability to switch between facilitating students operating freely to then guiding them in the process of revision and critique. Having resources and clear stages to your project plan to help this process is vital. This section outlines the typical stages of PBL and how to adapt it to a computing context.

The following questions can help you prepare to deliver a project with your students.

**Start with a driving question or mission:** The project goal for computing projects is often to create a digital product in response to a need or design brief with has a specific audience in mind. Add in detail and sense of linking to real world problems at this stage to maximise learner engagement. Decide the limits for students projects and outline these clearly from the start to avoid having to dampen down their enthusiasm. For example, if creating a 2D game instead of a 3D one is better suited to technical limits then be clear about that from the start of the project.

**Designing a plan and resources for the project:** Decide what part of the curriculum the project work will develop. Use a deep knowledge of the curriculum to put resources in place to support the learners as they undertake the project. Not everything needs to be explicitly taught if you can signpost your learners to those resources. Having an online repository that is for student to access and navigate can be extremely useful.

**Monitor pupil’s progress:** As the project unfolds, keep students on track by having a realistic schedule for project stages. Check that you are consistently signposting students to the relevant resources for the project choices they have made and the stage that they are currently undertaking.

**Assess emerging project processes and outcomes:** Ongoing feedback and assessment is vital. Building in opportunities for reflection, peer feedback and revision. Can students share prototypes of their digital products? Can you support then to recognise if they are working effectively as a team? How can you support them to make connections to the underlying curriculum knowledge?

**Evaluation:** You may evaluate both the end piece of work created by the student but also the way they have worked together and the skills used to undertake different stages of the project. You can validate what the students have learned and areas for future development.

If you would like more detailed information and case studies on this topic there are online resources provided by numerous PBL organisations including Edutopia, PBLworks and the UK-based Edge Foundation. This link provides a good overview. https://my.pblworks.org/

## Creatively Overcoming Limitations to PBL

This section looks barriers to PBL and tips and strategies that have been used by other educators and researchers to overcome these barriers in the context of computing and cross-curricular activities.

**Sustaining the effort - Time challenges:** In research on barriers to undertaking projects in schools, teacher commonly cite time restrictions due to curriculum pressures. Resnick and Rusk (2020) suggest that if possible, double lessons are helpful for hands-on work and to allow the design process some time to unfold. They also advocate that at times a whole term should be devoted to undertaking a project. This lets pupils return to tweak and improve trickier coding and design challenges, thus supporting a sustained and iterative approach. In addition, cross-curricular projects may free up more time by linking with other subjects which are allocated more time, especially in KS3. For example, you could link a computing project with mathematics by asking students to create a game that teaches mathematical concepts. This could both deepen students’ learning of particular mathematical concepts and allow for the kind of repeated hands-on practice that builds coding fluency.

**Advocating the Value of PBL for Inclusion:** As with design-based approaches, PBL aligns well with UDL, specifically in the was students can bring their own interests in their creation of a public project of their on choice and in the frameworks teachers provide to guide project work and ongoing feedback. As educators, we can highlight importance of creating inclusive classroom environments to our line managers to advocate for the time, training and resources needed to undertake project-based learning.

**Artefact-based Assessment:** The tension between rote-learning approaches often used to prepare students to reproduce knowledge in written exam questions and the need for more fluid programming experiences raises an important question. How can some of the more flexible techniques for observing and assessing learner progress be brought into exam practice to reduce the gap between exam and real life coding practices? As a possible response, the NCCE promote the use of Artefact-Based Questions (ABQs) to assess project work. Questions based on the digital or physical artefacts that students create as part of their projects allow teachers and students to identify the requirements of the computing curriculum to the problems students have encountered and solved in their computing projects. Teachers can focus in on specific areas of the programme and ask about details of the code structure and implementation. Questions can also address design issues and processes. For example, how the project outcomes compare to the original goals, how feedback was implemented, about group work and overcoming challenges and the design challenges.

**Authenticity of Project:** As mentioned before, computing is blessed with the potential to create digital and physical projects that are recognised or relevant to young people. However, sometimes the process of finding authentic audiences and processes to motivate learners within a school setting is not simple. The following activity may help you address this in your classroom.

### ACTIVITY - MEETING THE CHALLENGE OF AUTHENTICITY IN THE CLASSROOM

Here are some tactics you may be able to use linking projects to real issues beyond the classroom.

* Draw on community members to set a local challenge that resonates with your learners.
* Use other members of staff in other subject areas to pose a school-based problem. This could be subject-specific or a pastoral or cross-curriculum issue.
* Establish links with industry or social enterprises to set an authentic challenge within a work context.

If you draw on experts, staff or community members they do not need to be there for the full term of the project. You can use visits or video calls at the start and end of the project. Most importantly, be sure to draw on the experience of students and use their ideas to shape possible responses to the challenge in early stages.

## Conclusion

In much of the research surrounding motivation, participation and peer learning we see that learning does not happen in a vacuum. In computing, there is a clear value of creating a learning community of coders working on projects that are both authentic and linked to their own interests. To help this to happen, we can draw on some of the rich research and resources that are available from different streams of practice including project-based learning, UDL and design-based approaches. What many design and project-based approaches have in common is their focus on learner choice, sustained hands-on making and frameworks for facilitation, observation and assessment. For an accessible and convincing summary of project based approaches and their adoption in a classroom setting the review by Barron and Darling Hammond (2008) is inspiring- http://tiny.cc/pbl-summary.

We have explored the tension between creative processes involving learner choice and teaching to the more prescriptive requirements of the computing curriculum. To help bridge this gap the NCCE have created resources drawing on socio-cultural research to offer guidance on PBL, observation and pair programming. These resources are supported by articles from teachers, researchers and other practitioners in blogs and the computing education magazine Hello World. We are still in the relatively early stages of sharing our practices and resources as a community of computing educators. I hope that this chapter has encouraged you to keep exploring more authentic coding practices in schools and to share your experiences with others. To continue this journey there are many forums where teachers share practice; these include CAS forums, blogs, twitter posts and so on. To fully explore the potential of projects let’s share and encourage others to share how we have used design and PBL approaches in our work.

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