A Story Unfolding - Productive Mistakes in Making Design Learning Visible in an International Context

Klapwijk, R.M.; Stables, Kay ; Blom, Nicolaas ; Canty, Donal ; Dagan, Osnat ; Hartell, Eva ; Khunyakari, Ritesh

Publication date
2022

Document Version
Final published version

Published in
PATT 39 On the Edge Proceedings

Citation (APA)
Klapwijk, R. M., Stables, K., Blom, N., Canty, D., Dagan, O., Hartell, E., & Khunyakari, R. (2022). A Story Unfolding - Productive Mistakes in Making Design Learning Visible in an International Context. In D. Gill, J. Tuff, T. Kennedy, S. Jamil, & S. Pendergast (Eds.), *PATT 39 On the Edge Proceedings: Designing A Better World Through Technological Literacy for All* (pp. 256-265).

PATT 39

ON THE EDGE

TECHNOLOGY, INNOVATION & EDUCATION

PROCEEDINGS

DESIGNING A BETTER *WORLD* THROUGH TECHNOLOGICAL LITERACY *FOR ALL*

June 21 – 24, 2022
Memorial University,
St. John's, NL, Canada

Editors:
David Gill, Jim Tuff, Thomas Kennedy, Shawn Pendergast and **Sana Jamil**

MEMORIAL UNIVERSITY

MARINE INSTITUTE

PATT

100 years of excellence
FACULTY OF EDUCATION
MEMORIAL UNIVERSITY

Newfoundland Labrador
CANADA

Newfoundland & Labrador English School District

NLTA

CONSEIL SCOLAIRE FRANCOPHONE PROVINCIAL

PATT 39

PATT on the Edge

Technology, Innovation and Education

St. John's, Newfoundland and Labrador, Canada

June 21st-24th, 2022

Edited by:

Dr. David Gill
Memorial University
Mr. Jim Tuff
Memorial University
Dr. Thomas Kennedy
Memorial University
Dr. Shawn Pendergast
Memorial University
Ms. Sana Jamil
Memorial University

Faculty of Education
Memorial University of Newfoundland

ISBN: 978-0-88901-505-0

A Story Unfolding - Productive Mistakes in Making Design Learning Visible in an International Context

Remke M. Klapwijk[1*], Kay Stables[2], Nicolaas Blom[3], Donal Canty[3], Osnat Dagan[4], Eva Hartell[5], Ritesh Khunyakari[6]

[1]Delft University of Technology, Faculty of Applied Sciences, Science Education and Communication

[2]Goldsmiths, University of London

[3]School of Education, Faculty of Education and Health Science, University of Limerick, Limerick, Ireland

[4]Beit Berl College, Faculty of Education, Israel

[5]Department of Learning in Engineering Sciences, Department for Education, Haninge Municipality, KTH Royal Institute of Technology, Stockholm, Sweden

[6]Tata Institute of Social Sciences, TISS-Azim Premji School of Education, Turkayamjal, Ranga Reddy District, Hyderabad, India

[*]Correspondence: r.m.klapwijk@tudelft.nl

Abstract

This paper reports on a pilot project focused on the use of the formative assessment resource Make Design Learning Visible (MDLV) in different national settings. The MDLV resource centers on a design model involving seven interactive design skills and a formative assessment model involving five strategies. A team of researchers from seven countries in three continents, are working collaboratively with a teacher practitioner from each country to develop the structure of the research project and trial of a design activity that utilises the MDLV skills and approach to formative assessment. This paper reports on ongoing exploratory early work with the teacher practitioners trialing a short design project with an overarching theme of sustainability, a focus on developing two design skills (Empathy and Sharing ideas) and two formative assessment strategies ('Activating learners as resources for one another' and 'Activating learners as owners of their learning'). The project centers on a design brief customised for each national setting and relevant for learners aged between 10 and 15 years of age. A structured portfolio supporting an iterative design process forms the basis of tangible evidence of learner responses. The pilot is providing insights into the effectiveness of the MDLV resource in developing design skills and formative assessment across national settings. Additionally, the pilot contributes understandings of comparative participatory research involving teacher practitioners across countries. The exploratory nature of the early stages of the project intentionally allows some aspects to be customised locally by teachers as we seek to understand rather than dictate how the resource is best used in the local educational contexts. To this end, the overarching structure and pedagogy of the activity is fixed, but aspects such as lesson timings, choices around the use of MDLV tools and the further MDLV design skills are flexible.

Key Words: Design learning, formative assessment, comparative participatory research, practitioner researchers, peer feedback

1. INTRODUCTION

This paper reports on ongoing, exploratory research that has at its core formative assessment and skills of designing. The project has been developed from the *Make Design Learning Visible* (MDLV) resource, developed at the Delft University of Technology. This resource had been used across a range of schools in the Netherlands and, once translated into English, a small number of schools in England. The resource was presented at several PATT conferences and sparked interest amongst colleagues in other countries. On the basis of this interest, a collaborative international research team involving Ireland, India, Israel, Sweden and South Africa, alongside the Netherlands and England was formed.

The MDLV resource, Figure 1, centers on a design model involving seven interactive design skills - bring ideas to life, share ideas, make productive mistakes, think in all directions, develop empathy, decide on your direction and make use of the process and a formative assessment model (Figure 2), developed by Wiliam (2011), involving five strategies; clarifying and sharing design skills and success criteria, eliciting evidence of learning, providing feedback that moves learning forward, activating learners as resources for one another and activating learners as owners of their learning.

Figure 1. MDLV Design skills framework

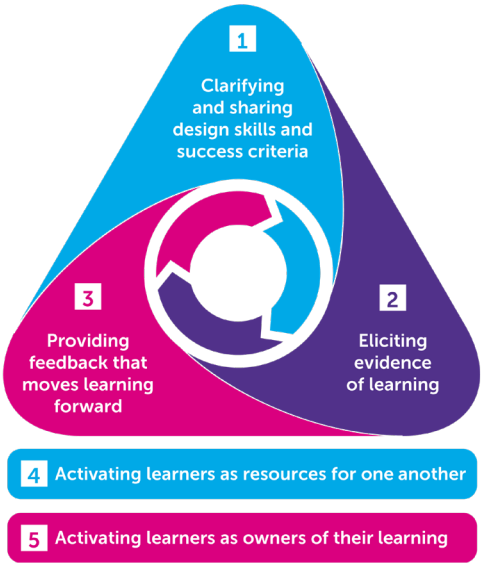


Figure 2. Wiliam's (2011) five formative assessment strategies

The overarching aim of the team is to explore the impact of the MDLV resource when used in different cultural and technology education contexts. Specifically, we aim to gain insights into teachers' different pedagogical approaches, and the challenges of sharing design based resources across cultures, languages and international curricula. We hope that these insights can support future endeavors to embed visible design learning and formative assessment practices into international design education curricula. This overarching aim is the long term ambition for the project. The information and insights presented through this paper are drawn from the early exploratory stage of our journey to achieve this aim.

2. LITERATURE REVIEW

The formative assessment model within the MDLV resource is holistic, embedded and makes learning visible through drawing insights from Wiliam (2011) and Hattie (2009). The resource provides

opportunities for teachers and learners to integrate assessment as a support for learning based on the reciprocal interaction between learner and teacher needs. Through the project based approach, seven design skills are developed through a choreographed pedagogical approach that embeds strategic and purposeful assessment (Kimbell and Stables 2007). The embedded design skills and assessment tools have their own clear focus enabling teachers and learners to identify and articulate different aspects of learning that is taking place, thus bringing learning to life and making it visible. However, a note of caution is that the choreography of the formative assessment approach does not dictate or disturb learners' processes of designing. The formative assessment tools furthermore contribute to the reflection and action iterations at the heart of designerly activity (Kimbell, Stables, Wheeler, Wozniak & Kelly 1991; Kimbell & Stables 2007) that support divergent and convergent thinking through the *having*, *growing* and *proving* of ideas (Kimbell, Miller, Bain, Wright, Wheeler, & Stables, 2005)

Learning is a complex process and embedding assessment as part of a learning task comes with challenges. In this complex process quite often pupils receive little feedback and have no clear view of the learning goals or the success criteria (Gulikers & Baartman, 2017). A mis-alignment between teacher and learner views of the learning goals and insufficient collection of evidence of learning can lead to practices of formative assessment that provide incorrect diagnoses of capability and low quality or no feedback that is critical to moving learning forward. To this end, clarifying design skills and success criteria creates a clear lens for eliciting evidence of learning which in turn can move design learning forward (McLaren, 2007). Providing this clarity was a key aspect of the development of the MDLV resource.

With a focus on peer and self assessment, learners develop the agency to activate both themselves and each other as learning resources in their own right. (Klapwijk, Holla & Stables, 2019). This agency allows students to take ownership of their own learning, by supporting them to set personal learning goals, develop strategies to achieve these goals, monitor their progress, and develop a sense of quality of their work through reflection and evaluation. Similarly, peer assessment broadens learners' view of possibilities and potential to both give and receive feedback, which is known to have a positive influence on learning (Moreland, Jones & Barlex, 2009). When structured pedagogically through learners acting as critical friends it also supports learners to develop skills of collaboration alongside becoming peer assessors (Costa & Kallick, 1993; Hakkarainen et al., 2013).

Although there is much focus on ways in which learners engage in designing, much current research focuses only on the stages and phases of designing. Few studies have explored the fundamental skills involved in design-based learning (Haupt, 2018). Of studies that do, few report on ways to assess and develop design skills in general (Kimbell & Stables, 2007). To this end, this study is concerned with developing design skills through using formative assessment tools, so as to contribute to the emerging body of research on design pedagogy. The aim of our research is to embed strategies to clarify learning objectives, collect evidence and provide feedback for the next steps in a design project in a powerful and connected way. The study will focus on both the context of the learning task and the integration of assessment and learning activities and the resultant impact on the practice of teachers and the experience of learners.

3. METHODOLOGY

3.1. Research Design

For this study, we will follow a Design-based Research approach (van den Akker & Nieveen, 2021). Design-based research involves the practical improvement or innovation of curricula, within realistic contexts and addressing the development of this curricula at various levels (student, teacher, researcher). We will emphasise five levels of involvement: a) Researcher-researcher, b) Researcher-teacher, c) Teacher-teacher, d) Teacher-learner, e) Learner-learner. The interactions on and between the different levels of involvement guides the iterations of the support materials.

3.2. Setting and Participants

Teacher participants for this study have been recruited mostly purposively and conveniently from the seven countries of the pedagogical leads (researchers). The aim is for each pedagogical lead to work with one or two teachers that express a willingness to engage in the curriculum design based research in their classrooms. A variety of selection criteria were used to choose participant teachers for this project. These criteria included experience in teaching design and technology related subjects, working with an age group of 10-15 years old, willingness to experiment with the MDLV toolkit and being able to adapt their teaching schedule for the 6 hour duration of the design challenge. Each teacher identified a class group in which to situate the research project. The selection criteria for the learner participants (class group) were that pupils should be between the ages of 10 and 15 years old and that they are studying a design based technology subject or equivalent in their country. The population sample for data used in this paper consisted of three teachers, with mixed teaching experience in a technology subject discipline. The full study has class groups consisting of eleven classes across seven countries.

Table 1. Contextual information about the research participants

Country	*Number of teachers*	*Level of experience in Design and Technology*	*Learner age group*	*Teacher selection methods*
The Netherlands	*2*	*Medium/High*	*11-12*	*Purposive*
UK	*1*	*High*	*11-12*	*Purposive*
Israel	*2*	*Medium*	*10-12*	*Convenience*
Sweden	*2*	*Medium/High*	*11–13*	*Purposive*
South Africa	*1*	*Medium/High*	*14-15*	*Snowball*
Ireland	*1*	*High*	*13-15*	*Purposive*
India	*2*	*Medium*	*11-13*	*Purposive*

3.3. Curriculum development intervention

Through a collaborative process, the researchers from each country met regularly to decide on an appropriate design challenge, appropriate for the different contexts in each country. A design task and portfolio used previously for assessment research was modified to form the basic structure of the classroom based project. (Kimbell e.a., 2005). The task and portfolio structure were chosen as a base as they provided an iterative design approach and had been used effectively with learners across a wide age range. The focus of the design brief was to re-design light bulb packaging so that it converted to a lighting feature, creating reuse rather than discarding the materials. The MDLV version was designed to integrate effective formative assessment practices developed by Wiliam (2011) and that form the basis of the MDLV assessment framework (Klapwijk and van den Burg 2020). For the exploratory project we chose to focus on *Activating learners as a resource for each other* and *Activating learners as owners of their learning*. To support this within the activity, while each learner had their own design task, they were seated in groups of three that worked as a team of critical friends to provide an opportunity to develop the design skill of sharing ideas and foster learners as partners in formative assessment (Costa & Kallick, 1993). A decision was made to highlight the MDLV design skills of empathy and sharing ideas and also a context of sustainability, all of which fitted the design context of the chosen task.

The purpose of the task and portfolio was to provide opportunities for curriculum materials to be developed that would support teachers from the participating countries in implementing effective design pedagogy.

We aimed to support teachers in cultivating learners' design skills and use formative assessment to move learning forward, while addressing issues of sustainability and empathy. To do this the research team developed user personas, a choreographed portfolio, a modeling kit, a handling collection, a slide deck and teacher guidelines. These were accompanied by the MDLV toolkit, with five tools strategically integrated into the portfolio to support learning through formative assessment activities. The teacher guidelines supported them at each stage of the activity. Figures 3&4 illustrates how this was approached showing an example of the learners' first task and the teachers' corresponding guidance.

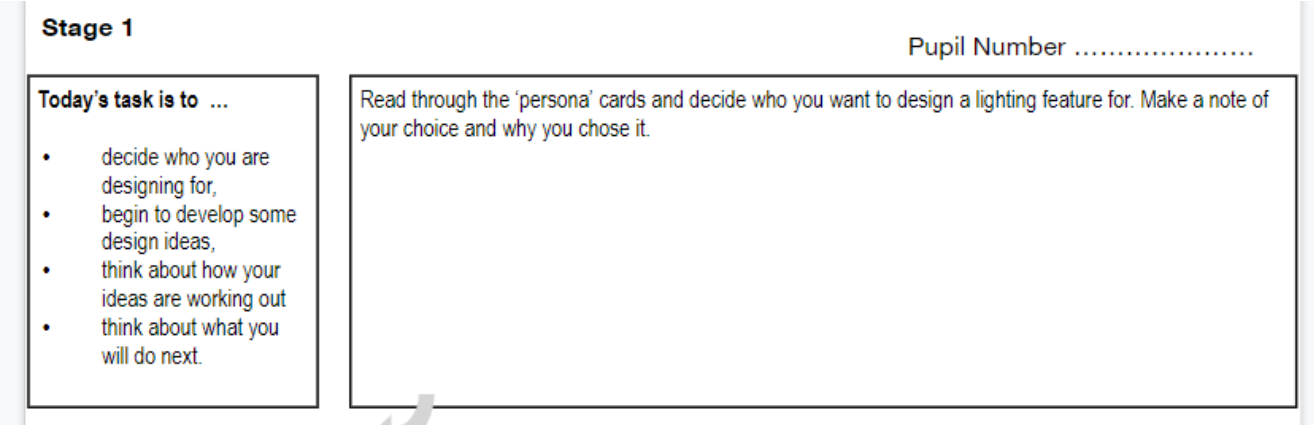
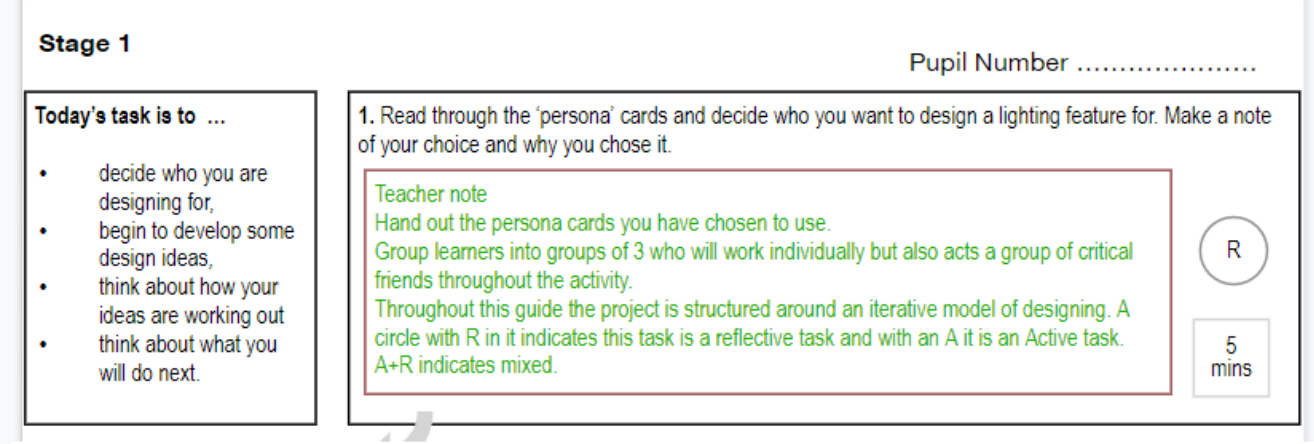


Figure 3. Extract from pupil portfolio



Stage 1
Box 1 note – persona cards.
There are a choice of 7 persona cards. It is up to each teacher to decide how many and which ones to use. Learners should be shown all cards and be allowed to choose the 'persona' that they will design for. This is a key tool for helping learners to focus on the needs and wants of a user and to develop empathy for their persona as they design to meet their needs. Taken together with the requirements of the light bulb company each learner will have a set of things to consider whilst designing.

Figure 4. Extract from Teacher Guide

3.4. Data collection

In this pilot, we use qualitative data collection methods. All data will be documented into textual information that can be analysed. For this paper we only present data from three schools where early trials have started that focuses on Researcher-Teacher interactions.

Table 2. data collection methods based on the four levels of interactions

Levels of interaction	*Data collection methods*
Researcher-researcher	*Video recordings, personal reflections, group reflections*
Researcher-teacher	*Unstructured interviewers, semi-structured interviews, discussion notes*
Teacher-learner	*Classroom observations, design tools, design portfolio* *Unstructured interviewers, semi-structured interviews*
Learner-learner	*Design portfolio* *Classroom observations* *Unstructured interviewers, semi-structured interviews*

3.5. Data Analysis

To analyse the data, we will follow Braun and Clarke's (2021) guidelines for conducting thematic analysis. This method will allow us to engage in a process of systematically identifying, organising, and generating deductive and inductive themes across the various data sets.

4. INSIGHTS FROM EXPLORATORY PILOT STUDY

4.1. Has design learning become visible? Initial insights from Netherlands and English trials

The exploratory project is in the early stages. Here we present initial insights from trials in three schools, two in the Netherlands and one in England. Both schools in the Netherlands work with gifted children. One teacher is very experienced in D&T teaching, the other has some experience. The age of the children involved was 11-12 years. The researcher held recorded discussions with the teachers in advance and was present in the lessons. The school in England has learners of mixed abilities. The teacher involved is experienced in teaching D&T. The children involved were aged between eleven and twelve years old. The researcher held recorded discussions with the teacher in advance and between lessons but was not present in the classroom. Initial discussions focused on the nature of the classroom project and the resources presented (the choreographed portfolio, persona cards etc) and the ways that formative assessment were integrated into the project. The focus on the highlighted design skills of developing empathy and sharing ideas and on sustainability was discussed, along with the teacher guidelines.

The need for and development of the teacher guide emerged as a *productive mistake* of the research team. Both the activity portfolio and the guide were created in English and based on approaches from England. The guide itself was initially minimal. Using this with the earliest teacher to start, whose first language

was not English raised immediate challenges including a misunderstanding of an aspect of the design task. This resulted in a more developed version that not only provided clearer and more detailed guidance for the teachers but also greater understanding of curriculum differences amongst the research team and the value of an exploratory approach in the first stage of the project.

In respect of making the design learning visible, four aspects stood out in the early trials. The first of these was developing understanding of the term 'empathy' and then seeing how the learners' understanding of the term impacted positively on their designing. IDEO (2015) has identified empathy as a foundational principle of design thinking and increased interest in the value of user-centred design has raised the awareness of empathy as a design skill that can be developed in young learners (Bosch et al., 2022). A key strategy we are researching in this context is the use of persona cards that provide user details. Seven cards were created for teachers to choose from. The personas included people of different genders, age groups and diverse backgrounds. One of the teachers from the Netherlands chose to use seven and the other to use four. The teacher in England chose three. Figure 5 gives an example.

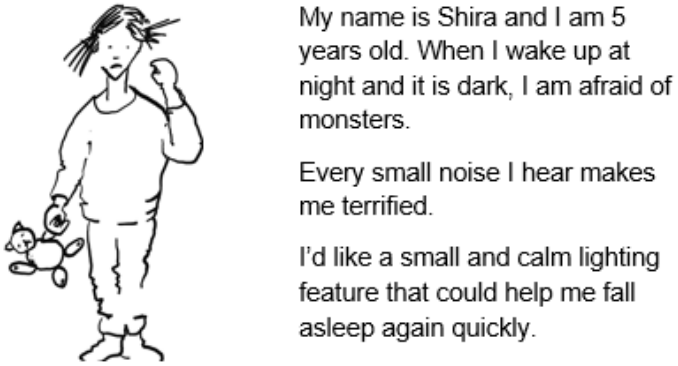


Figure 5. Example of persona card

In making his choice, the English teacher was influenced by having personas that the learners could relate to but that also broadened their experience of different people and their needs.

> "I need to make sure that the three [chosen] are ones that can be relatable to the kids, they understand it, but at the same time ... I want it to challenge their perceptions on different people from different cultures and different backgrounds … these are people from around the world and actually as a designer you could be faced with this problem, how do you respond to it? No prejudice, no bias, anything like that, you just go open minded, open book, to really resolve that issue."

One teacher in the Netherlands developed the approach further by identifying the director of the light bulb company as a stakeholder, creating a different perspective on empathy.

From the conversation between learners in all three schools it was evident that the personas stimulated understanding and evidence of showing empathy. They were able to select a persona in a limited time and – at first sight – identify with the person depicted, talking about what the person would like etc.

There was also evidence of teachers activating learners as a resource for each other, supporting a learner who did know what empathy meant to share his understanding with others. This linked to the second aspect that stood out clearly from the early trials – formative assessment evidence of activating learners as resources for one another and as owners of their own learning. A challenge created by the Covid Pandemic identified by the English teacher was that learning being moved online had negatively impacted on learners' ability to work collaboratively. Using the strategy of learners working in groups of 'critical friends' (Costa

& Kallick, 1993) provided a constructive approach to self and peer formative feedback. In addition it also supported developing learners' collaboration skills (Hakkarainen et.al., 2013).

> "That formative evaluation that is taking place … and they could quite easily give that feedback to that other student because they were working in that group of three and also it relied on each person in that group … it allows them to be more fluid in their responses and their design work."

A third aspect that emerged was the impact on divergent thinking – the MDLV design skill of *think in all directions*. The use of 'handling collections' of objects disassociated from the context but that contained a concept that could be applied when developing the lighting feature became valuable here. An example of this came from a learner in the Netherlands who had ideas inspired by an unfolding 'pop out' map. She showed the researcher two additional ideas derived from the way the map worked and told her of ideas beyond the school project such as using the approach to wrap a gift. It was also observed that the handling collection changed the kind of drawings and designs children were making as they developed new ideas. Also designing was through mental imaging and gesturing, less on paper, with divergent thinking not being used exclusively at the start of the activity (Kimbell e.a., 2005).

Finally, we are aware of the impact that trialing the resource is having on teachers. Despite being an experienced teacher and curriculum leader, the English teacher is already seeing aspects new to him that he wishes to share with colleagues and build into his curriculum model for D&T, particularly the active/reflective in-the-moment model of iterative designing and the learning that comes through the portfolio. In his words,

> "For me, the big thing that … has sparked ideas for me … the different sheets are so easily applied to the learning … that I want to build that into other areas of my curriculum model. I've seen that it is hugely beneficial to their learning."

4.2. Affordances and constraints of an international team

Working together to build a research project with colleagues across seven countries (The Netherlands, UK, Ireland, Sweden, South Africa, India and Israel), is an exciting prospect and one that provides many opportunities. Earlier interests on assessment and designing between Delft and Goldsmiths universities sowed the seeds of a project that has far greater potential than had been imagined. The solid foundation of beliefs in the importance of formative assessment for learning, the iterative nature of designing and of the pedagogic and assessment strategies developed in each, fueled our initial discussions. The quality and potential of initial discussions has grown through conversations with colleagues across seven countries and a strong base for an international collaborative and comparative ambitious project has been created. Early discussions resulted in a high level of excitement as ideas grew alongside our ambitions. However, this level of ambition was quickly recognised as a challenge that had to be managed, which created some interesting and unexpected realities.

As each one of us came from different D&T situations and backgrounds, the development process of the learners' activity, the teachers' guide and other resources to be developed we acknowledged both similarities and differences. In South Africa, Ireland and Israel for example, teachers might not agree on what designing is, nor have similar views on implementing it in classrooms. We found that some are passionate to find new ways of implementing design based learning while others seek ways to make it efficient and manageable from a teachers' perspective. Some teachers are experienced D&T teachers, motivated to experience this project and exchange ideas with teachers from other countries. Other teachers are from different disciplines and need support to develop confidence with a D&T approach.

The MDLV framework provides a tool to make students aware of their design skill development and moves beyond just following 'the design process'. The fact that this framework is currently being used by other teachers in different countries is making the teachers excited to be a part of this project. One of the most exciting features for the teachers is to share their own classrooms with other teachers.

Collaborating with professional members of the design pedagogy community from different countries is an enriching experience. Working towards a goal of developing design pedagogy through the use of formative assessment brings both opportunities and challenges. For example, we discovered uncharted territory in terms of focusing on developing empathy and agency through the medium of design. Meanwhile, implementing a more-or-less similar intervention to develop empathy and agency through formative assessment in different contexts is not straightforward. In terms of the intervention design, there were several factors to be consider such as age and stage of development, prior experience in design based learning, time allocation for 'design lessons', teacher experience and willingness to take pedagogical risks. Particular consideration had to be taken into account for accessibility to resources. Some countries have fully equipped design studios, others might only have access to tables and chairs. How would the sharing of resources be facilitated, taking into consideration various languages spoken in each country? To develop empathy in different context also brings challenges. How well would a child in South Africa be able to empathize with an adult in Sweden? What level of understanding do teachers in different settings have of iterative processes of designing?

Issues have arisen as we have developed the project and, in the process, we have moved forward by making productive mistakes as is exemplified by the earlier account of developing a teacher guide. Understandings have become blurred as meanings are 'lost in translation', even between team members who speak the same language! Each misunderstanding has become a learning opportunity as a productive mistake takes us forward in our own learning as the project develops. As a research team we are embodying the MDLV design skills as we think in all directions, make productive mistakes, share understandings and show empathy.

5. NEXT STEPS

As we learn from the initial exploratory pilot cases, we will adapt materials and procedures to suit the teaching and learning needs of participating schools. By adapting, our hope is to refine existing tools and develop new tools to support the implementation of the MDLV framework internationally to support effective implementation of design pedagogy practices.

Building on initial findings, we aim to establish a community of practice between participating schools. This will allow teachers to learn from and share effective design pedagogy practices. We also plan to connect learners from different countries with each other, through the use of Adaptive Comparative Judgment (ACJ) as a formative feedback tool. By doing this, students can develop constructs of quality in providing feedback on each others' design skills.

Our hope is to promote design based learning as a means for developing learner's agency in thinking and taking action on unfavorable situations in their local community. By making the design learning explicit, we hope to develop learners' capacity to take ownership of their own learning and recognise when their skills enable them to act in designerly ways on everyday challenges.

6. REFERENCES

Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Design Empathy in Students' Participatory Design Processes. Design and Technology Education: An International Journal, 27(1), 29-48.

Braun, V. & Clarke, V. (2021). Thematic analysis: A practical guide. Sage Publications Ltd, London. UK

Costa, A. L., & Kallick, B. (1993). Through the lens of a critical friend. Educational leadership, 51, 49-49

Gulikers, J., & Baartman, L. (2017). Doelgericht professionaliseren: Formatieve toetsingspraktijken met effect! Wat doet de docent in de klas? Wageningen Universiteit, Nederland.

Hakkarainen, K., Paavola, S., Kangas, K., & Seitamaa-Hakkarainen, P. (2013). Sociocultural perspectives on collaborative learning: Towards collaborative knowledge creation. The international handbook of collaborative learning, 57-73.

Hattie, J. (2009) Visible Learning: A synthesis of over 800 meta-analyses relating to achievement. Routledge.

Haupt, G. (2018). Design in technology education: Current state of affairs. In M. J. de Vries (Ed.), Handbook of technology education (pp. 643–659). Berlin: Springer.

IDEO 2015 The field guide to Human-Centred design. IDEO.org

Kimbell, R., Miller, S., Bain, J., Wright, R., Wheeler, T., & Stables, K. (2005). Assessing Design Innovation: a research and development project for the Department for Education & Skills (DfES) and the Qualifications and Curriculum Authority (QCA. Goldsmiths, University of London.)

Kimbell, R., Stables, K., Wheeler, T., Wozniak, A., & Kelly, V. (1991). The Assessment of Performance in Design and Technology: The final report of the Design and Technology APU project. Evaluation and Monitoring Unit. SEAC / HMSO.

Kimbell, R., & Stables, K. (2007). Researching design learning: issues and findings from two decades of research and development. Dordrecht: Springer.

Klapwijk, R.M., E. M. Holla & K. Stables, 2019. Make Design Learning Visible, Delft, Delft University of Technology.

Klapwijk, R. and N. van den Burg (2020) Involving students in sharing and clarifying learning intentions related to 21st century skills in primary design and technology education. Design and Technology Education: an International Journal, 25 (3), 8-34. ISSN 1360-1431. Available at: https://ojs.lboro.ac.uk/DATE/article/view/2788

McLaren, S. V. (2007). An international overview of assessment issues in technology education: Disentangling the influences, confusion and complexities. Design and Technology Education: An International Journal, 12(2).

Mioduser, D., Dagan, O. (2007). The effect of alternative approaches to design instruction (structural or functional) on students' mental models of technological design processes. Int J Technol Des Educ 17, 135–148. https://doi.org/10.1007/s10798-006-0004-z

Moreland, J., Jones, A. & Barlex, D. (2008). Design and Technology Inside the Black Box: Assessment for learning in the design and technology classroom.GL Assessment

Van den Akker J and Nieveen N (2021) Combining curriculum and teacher development through design research. In: Philippakos Z, Pellegrino A and Howell E (eds) Design-Based Research in Education: Theory and Applications. New York: Guilford Press.

Wiliam, D. (2011, 2018). Embedded Formative Assessment. Solution Tree Press