Developing the Teach21 Online Authoring Tool
Supporting Primary School Teachers
in Designing 21st Century Design based Education

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Keywords: Design based Education, Authoring Tool, Primary Education.

Abstract: Students need to learn '21st century skills'. However, teaching materials for this are scarce. Moreover 21st century teaching is adaptive and teachers often need to design teaching materials themselves. Design Based Learning (DBL) is a promising approach for teaching 21st century skills. This paper describes the development of a tool to support primary school teachers in creating 21st century skills teaching materials, DBL materials in particular. After defining initial requirements, the study moves on as 'design research' comprising iterative design rounds. The resulting tool largely fulfils the stakeholders' and teachers' expectations, supports teachers in creating 21st century education and activates teacher reflection, even though it does not yet produce classroom ready material. To be effective in promoting DBL, it is necessary to further elaborate the concept of DBL and to supplement it with an explicit pedagogical strategy and concrete assessment procedures.

1 INTRODUCTION

As in many other countries Dutch education is changing to meet future challenges. So called 21st century skills are identified as critically important (Cogan & Derricott, 2014; Rotherham & Willingham, 2010). Primary education has to change, but this is challenging for most teachers. In particular since 21st century teaching typically requires students to work in groups and learn from open-ended authentic projects with relevance for the students and their local environment. For this type of education, only few teaching materials are available. The materials need to be tailored to the students' needs and the situation. This demand that teachers create their own materials.

Teachers need support for developing such teaching materials. Firstly to provide them with 'pedagogical models' and examples that underpin 21st century teaching, a way of teaching sometimes new to them. Secondly, to support and guide them in the process of designing education. This support can (best) be delivered online.

This paper describes the creation of an online tool that supports primary school teachers as reflective practitioners in designing 21st century teaching. It uses the 'pedagogical model' of Design Based Learning (DBL).

2 BACKGROUND

Many Dutch teachers are convinced of the need for changes in their teaching approach and are motivated to implement these changes. Apart from challenges such as taking a more coaching role in classroom, a key challenge is the lack of teaching materials. This requires design tools that also store the lessons designed to help teachers and to allow them to effectively profit from earlier initiatives. Moreover, the changing practice is such that teachers must design their own – student tailored - materials, putting an even greater demand on their competencies. Finally, the examination syllabus has not (yet) been fully adapted to the renewal, and teachers have to combine the new challenges with the classical curricular aims ('kerndoelen'), that concern knowledge and (mainly) instrumental skills.

Teachers meet various challenges in designing 21st century learning activities. Firstly, teachers have worries about learning goals and assessment. For example: how to make sure that the projects effectively address the various 21st century skills? How to make sure that all of the obligatory 'classical aims' such as mathematics or language skills are well-covered? How to efficiently move forward to

create learning activities that have the right balance between 'classical aims' and 21st century skills?

Secondly, teachers lack the skills and experience of educational designers. In educational literature, a variety of educational frameworks for developing classroom materials is available. For example, the curricular 'spider-web' schema by Van den Akker, Gravemeijer, McKenney, and Nieveen (2006). Such frameworks can stimulate and structure educational design. However, teachers are usually not acquainted with these, and these resources should be made available to the teachers in an easy-to-use way.

Thirdly, teachers may have no clear view of what the new education would look like. Coherent and challenging projects are needed and *Design Based Learning* (DBL) has been put forward as a model.

2.1 Design Based Learning

Design Based Learning (Bekker, Bakker, Douma, Van Der Poel, & Scheltenaar, 2015) is a teaching approach in which students learn by collaboratively creating designing solutions to open (societal) challenges. DBL allows students to work on authentic challenges. This often leads to intrinsic motivation and deeper insights into how the learned knowledge and skills can be applied in practice.

DBL is a form of 'inductive learning' (Prince & Felder, 2006) with the potential to provoke a major shift in educational practice and constitute a new pedagogy which might transform education (Sharples et al., 2016). DBL can promote design thinking which directly contributes to 21st century skills. It is generally defined as "an analytic and creative process that challenges the learner to experiment, to create and prototype models, gather feedback, and to redesign" (Razzouk & Shute, 2012, p. 330).

In this study a more precise description of the characteristics of DBL is needed for developing and evaluating the design tool. Gomez Puente, Van Eijck, and Jochems (2013) have described properties of DBL through an extensive literature review and a subsequent empirical validation in higher education. This framework was used in earlier studies to define characteristics of DBL in primary and secondary education (Bekker et al., 2015; Scheltenaar et al., 2015). From this a set of DBL-characteristics is defined for use in this study (Table 1).

2.2 Online Teacher Support Systems

Online support of teachers designing education has been extensively studied (McKenney, Nieveen, & Van den Akker, 2002). In this, a principal dilemma is the trade-off between flexibility on one hand, and structuring, channelling, guiding and scaffolding design choices (Pérez et al., 2017) on the other. It is key to find an effective balance that limits design-space in support of teachers yet respects teachers' professional autonomy en encourages their reflectiveness.

Table 1: Characteristics of Design Based Learning.

- An authentic design task relevant to student (and society)
- Requires knowledge to be activated and collected
- Allows students to choose their step and encourage student reflection
- Comprise design-steps; divergent and convergent thinking in particular.

Designing learning tasks comprises an overwhelming number of interrelated choices leading to massive cognitive (over)load for novices (Sweller, Ayres, & Kalyuga, 2011). For teachers that are novices or inexperienced in the type of teaching to be developed, the time needed for designing and preparing a lesson may be over 10 times the duration of the lesson itself.

Novice teachers and teachers confronted with an innovation new to them lack insights underpinning the innovation that could guide design decisions (see Vos, Taconis, Jochems, & Pilot, 2011). Clearly tools and exemplars are needed. Furthermore, teachers should have access to the rationale behind the innovation. This could provide criteria for considering various design options and can support them in making design choices.

To support designing teachers, it is crucial to reduce the 'design space'. A first component is structuring the design process. This takes away much of the interrelatedness of the various design choices which is difficult to understand for the novice teacher/designer. Structuring can be less strict for more proficient teachers/designers that already can understand the 'when and why' of various choices (Silver, 1991). A second component is to make design options transparent, and to reduce their number through pre-selection.

To make websites that present complex processes or situations in an intuitive and predictable way, these should be structured according to users' mental model(s) of these processes or situations. An example is the lay-out of the railway station manager's dashboard. Hence the online design tool should be organized according to the teachers' perception of the process of 'planning education'. This model can be found by examining how a representative groups of teachers views this (Bernard, 2000; Roth, Schmutz, Pauwels, Bargas-Avila, & Opwis, 2009).

Structuring the design process and pre-selecting design options alone would 'robotize' the teachers'

design process, frustrate teachers as autonomous professionals and hinder their development as reflective practitioners (Schon, 1984). Hence the online support system should give room for teachers' professional autonomy and professional decisions. Moreover, it should stimulate reflection while designing education. Even more so for designing DBL since reflection is in the heart of the design process itself (Bekker et al., 2015).

Hence, structuring and pre-selection of design choices should be minimized, but must also be rigorous enough to prevent cognitive overload. Scaffolding and guidance to support teacher in taking the remaining design-decisions is key. Jackson, Krajcik, and Soloway (1998) have developed such an adaptive strategy: Guided Learner Adaptable Scaffolding (GLAS). They distinguish 3 types of scaffolds: supportive (e.g. advise, highlighting options), reflective (e.g. clarifying alternatives and criteria, asking for deliberations), intrinsic (e.g. relating to the design process as a whole).

3 AIM

The central Aim of the study is to create a tool supporting primary school teachers in creating DBL with a productive balance between structuring, guiding and reflecting, that also is well implementable. It should also promote DBL and design thinking in education.

3.1 Research Questions

The central question in this project is: *Can an online tool be developed that supports primary school teachers creating 21st century lessons that include 'classical learning goals' using DBL?*
Specific sub-questions are:

a) Does the tool support teachers in designing and in reflecting during design?
b) Is the tool well adopted and implementable?
c) Does the tool effectively promote DBL as a pedagogical model?

4 RESEARCH/DESIGN METHOD

The projects was set-up as an educational design research project. Such projects move forward in rounds in which design – and testing/evaluation alternate (Van den Akker et al., 2006). Evaluation in often carried out using a multi method approach in which the results of e.g. material-analysis, classroom observations and interview or questionnaires are combined (Meijer, Verloop, & Beijaard, 2002).

The various data sources principally address the education to be evaluated at different curriculum levels (Goodlad, 1979). Interviews with teachers – for example - address the 'perceived curriculum', whereas classroom observations address the 'observed curriculum'. Hence, the data from the various sources supplement each other. Alignment and discrepancies point out the level to which the 'intended curriculum' was actually transformed in 'classroom reality'. These 'levels of curriculum are also found in the evaluation scheme (Table 2).

Table 2: General evaluation scheme.

	Curriculum level			
	T	P	M	E
General **A**spects of education: goals, methods, evaluation, … (Van Gelder, Peters, Oudkerk Pool, & Sixma, 1973)				
Adoption and **I**mplementation: Understandability, Usefulness, Easy to use, Congruence (Doyle & Ponder, 1977)				
DBL characteristics: Structure, Steps, Reflection (Rotherham & Willingham, 2010; Scheltenaar, van der Poel, & Bekker, 2015)				
Teacher **G**uidance: Structure / Fit to teachers mental model, Option reduction / Cognitive Load, Guidance, Reflectiveness, (Kirschner, Sweller, & Clark, 2006)				
Learning **G**oals within DBL created: Classical learning goals, 21st century goals				
Goodlad (1979) levels of curriculum: T = Theoretical curriculum: analysis of the tool, expert panel, user interviews P = Perceived curriculum: teacher interviews, classroom observations M = Material curriculum: analysis of classroom materials E = Experienced curriculum: classroom observations, student interviews				
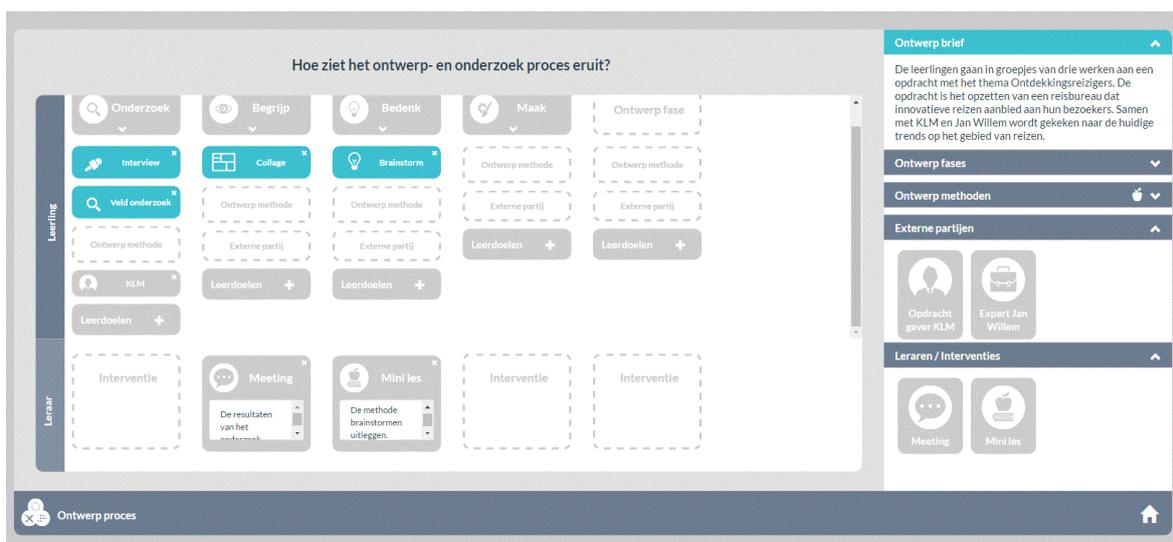
Figure 1: Screenshot from the initial tool.

4.1 Evaluation Scheme

Data collection and analysis was organized according to the evaluation scheme shown in Table 2. Five 'main variables' are evaluated on 4 of the Goodlad - curriculum levels: Theoretical, Perceived, Material and Experienced curriculum. For each level particular data-sources are available (bottom row in Table 2). When used, the cell of the scheme fill, and comparison of the findings in one row over various columns reveals how the intentions underpinning the tool worked through in e.g. teacher perceptions, teaching materials created and/or classroom reality.

The categories reflect the studies research questions. The first category is fundamental to evaluate the general effects off the tool on the created education and concern general aspects of learning environments according to (Van Gelder et al., 1973). The second employs the work of (Doyle & Ponder, 1977) on adoption of educational innovations and implementability. Key factors considered here are: understandability, usefulness, 'easy to use', and congruence with the teachers convictions.

The third category ensures the evaluation of the way the tool addresses the various DBL components (see Table 1). The fourth category focusses on teacher support and the stimulation of reflection. The fifth category concerns the educational goals.

4.2 Setting and Respondents

Data were collected from expert panels, stake-holder panels, user sessions, user interviews, analysis of the tool, analysis of the classroom material designed, and classroom observations. Five teachers and four stakeholders participated in the project. They were all from the PlatOOlab (2017) group of schools. This is a regional network of primary school collaborating in modernizing education in close cooperation with educational institutes and the city administration. Expert panels comprised 12 experts with expertise in educational design, educational research and/or teacher training. The main researcher worked in close cooperation with the design team, but was not a member of it.

5 STUDY DESCRIPTION

5.1 Initial Specifications and Tool

At the start of project a preliminary tool by Van der Sanden (2016) was used as input for two stakeholder meetings with PlatOOlab school-leaders and leading teachers. Also a panel of 6 experts was asked to give feedback on the preliminary tool. Finally, existing tool-kits for supporting teachers in teaching 'design' were evaluated (e.g. IDEO, 2013). This led to a list of must-haves, should-haves and could-haves. Implementation of particularly the must-haves led to the initial tool used in the first round.

The initial tool (Figure 1) provides support for handling the openness of the design activities, 2) linking a design problem/challenge to a theme and learning goals, 3) building up a set of learning activities linked to concrete learning goals, 4) selecting design methods related to design phases, 5) selecting collaboration forms for the different learning activities.

Table 3: Main results of design round 1.

	T	P	M	E
GA	Not all lesson-components are addressed in the tool e.g. homework, assessment	(nevertheless) teachers consider all lesson-components	(all lesson-components occur)	✕
A&I	Workflow not always clear, no classroom ready output (limited understandability)	Aims fit very well to teachers' view of modern education (congruence)	No classroom-ready products (low usefulness)	✕
DBL	The concept of DBL is partly implicit in the tool e.g. only implicit support on 'design specifications'	No mention	Student material contains 'design specifications'	Teacher removes 'design specifications' as un could-have during the lessons.
TG	The tool structures the design process, presents alternatives addresses the way teachers should design only implicitly	Teachers are challenged to explore design options and report being more reflective	✕	Teachers reflect during teaching and make adaptation to the lessons
LG	Tool comprises a list of classical learning aims which is unconnected to design-activities	No mention	Absent	Classical learning aims play no role in the lessons

5.2 First Design Round

In the first round five teachers were interviewed about the tool, and three teachers were observed while working with the tool. Teaching materials developed were evaluated, and 4 lessons previously designed using the tool were observed in classroom. Both the teachers and the students were observed.

5.2.1 Results

Overall, the tool is used as intended. While using the tool the teachers struggle with the workflow which is sometimes 'a bit illogical' or unclear. The workflow in the tool also differs from what these proficient teachers usually do when designing education, and comprises typical design-activities which they are still unacquainted with.

Table 3 shows the results in the format of the general evaluation scheme, which we will discuss row by row. The first row shows that some general aspects of learning activities (e.g. homework, assessment) lack in the tool. The teachers were able to compensate for this and arrive at complete educational arrangements nevertheless; but this critically depends on their (apparently sufficient) proficiency as designers.

The second row shows that the initial tool scores high on congruence, but low on usefulness and understandability – which is in line with the findings in the first row. The third row shows that the tool only partly succeeds in making clear the concept DBL on a theoretical level. This appears echoed in the 'P-column' where the concept is absent, and the 'E-column' where the key DBL-concept of 'design specifications' is removed during the lessons in classroom immediately after a brief introduction. Apparently the tool did not clearly convey that this concept is key to DBL.

The finding in the fourth row shows that the tool is effective in guiding the teachers. No signs of cognitive overload (e.g. confusion) were observed. Finally, row 5 indicates that the 'classical learning aims' apparently get lost during the design of DBL learning activities.

5.2.2 Adaptations

In round 2 it was concluded that the structure of the tool should be made more clear and should primary reflect the teacher mental model of 'lesson planning' thus including for example homework and test.

The guiding-strategy apparently worked but could still be improved after the removal of incoherencies in the support of the first phase of educational design. The previously existing 'design skeleton' comprising 3 phases: Meta description (level, subject, theme, central-question etc.), Choosing matching activities, Elaborating chosen activities was implemented more rigorously. Teachers can however leap forward, backward, upwards and downwards while using the tool.

This firm skeleton allowed for a more systematic implementation of the key elements of DBL, for a better pre-selection of e.g. design activities on the basis of element in the meta-description, and for making connections between classical learning goals and design-activities. Effort was made to have the tool produce classroom-ready products wherever possible.

5.2.3 Second Design Round

Due to the overhauling of the skeleton the second version of the tool had to be completely rebuild in another platform (Bakker, Bekker, & Taconis, 2017).

The new tool provides a better structure for the teachers to decide on various elements of the lessons to be developed, such as learning goals, educational activity, length and mapping to design phases. The tool takes them through a process of first deciding on the global theme of the design activity, the intended students, and the deliverables (steps one and two in Figure 2). It then helps them to decide on how many lessons to design, the linkage of the lessons to what design activities, and choosing the design methods that will be incorporated in the lessons (step 3 in Figure 2).

Research in the second design round comprised an expert review by (8) educational experts. Also the improved tool was used by 4 teachers with a researcher present. The design product resulting from these sessions was analysed. Teachers-users and stakeholders were interviewed. Unfortunately no classroom use was possible due to logistical issues.

5.2.4 Results

The general picture is that the teachers-users are very happy with the new tool. Those who have used the initial version agreed that the revised tool is much better structured, more informative, and more useful. Table 4 shows the results in more detail. The first two rows show that the tool now is a more clear, complete and usable design support tool, that comprises all aspects of and components of lessons to be planned. The clear skeleton contributes to this. The tool also is adequate in stimulating informed reflective design decisions (row four).

However (row three) shows that the concept of DBL still stays implicit. Users primarily value the tool as an instrument for designing 21st century education in a structured and reflective way. Besides this, the second version of the tool did not succeed in connecting 21st century aims and classical learning aims to the DBL learning tasks designed.

Table 4: Main results of design round 2.

	T	P
GA	All lesson-components are in the tool	Teachers consider all lesson-components
A&I	Workflow is clear, output of use to teachers	Fits very well to teachers' convictions of modern education; output usable
DBL	The concept of DBL is clear.	Teacher value the tool for the structured way of designing modern education (rather than DBL per sé)
TG	The tool follows the mental model of 'lesson planning' and guides teacher choices on learning activities	Teachers report being more reflective; and are inspired by the suggested learning activities
LG	21st century aims and classical learning aims are pre-selected form meta-description	No mention
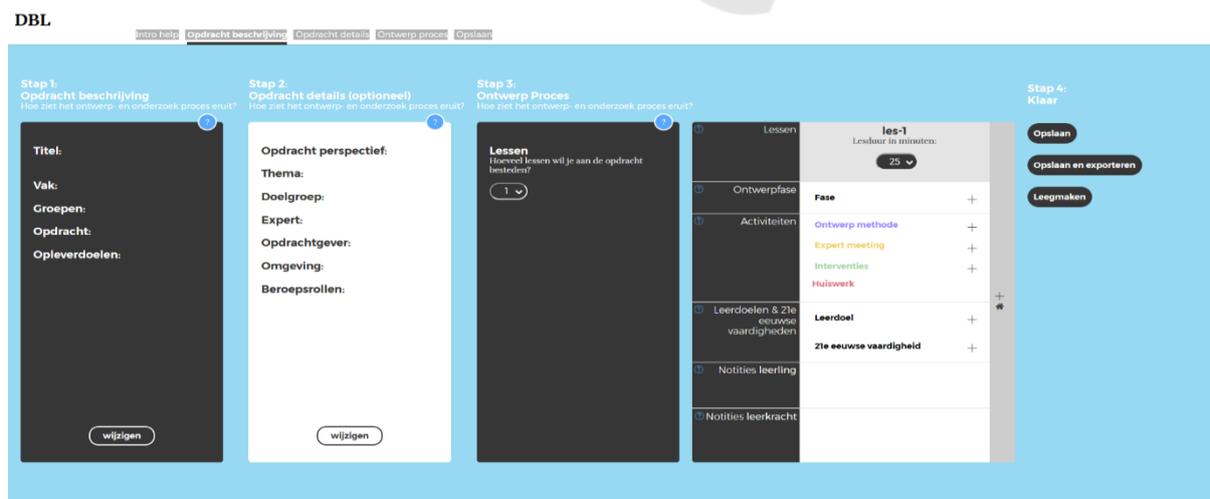
Figure 2: Screenshot of the revised tool.

6 CONCLUSION & DISCUSSION

Teachers and stakeholders value the design tool as an instrument for designing 21st century education in a structured way that also stimulates reflection. The tool appears to be successful in this. However, it was not found to be effective in promoting DBL.

Besides this, it remains unclear what exactly are the learning effects of the DBL education that was designed using the tool. Moreover, the tool can clearly be improved in connecting specific '21st century learning goals' and 'classical learning goals' to the DBL education designed. Two things seem critical to make further improvements.

Firstly, the concept of DBL needs to be supplemented with a pedagogical strategy that describes the particular cognitive demands of the design activities. Thus allowing to link these to skills and knowledge needed to complete these. For this the 'levels of inquiry' by Ireland, Watters, Lunn Brownlee, and Lupton (2014) may be used. This would also allow for a better underpinning of the pre-selection of design options presented in step 3 on the basis of the 'global decision' made in step 1 and 2.

Secondly, assessment should get more attention in future projects. Assessing of 21st-century competencies is beyond the capabilities of most traditional assessment formats (e.g., multiple-choice test, self-report survey)' (Razzouk & Shute, 2012, p. 330). As students work on their tasks, evidence can be collected to evaluate their performance. But teachers need support in this. The design tool should preferably offer assessment formats that teachers can use to create adequate assessments as an integrated part of their DBL.

ACKNOWLEDGEMENTS

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