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Digital Didactical Designs as research framework: iPad integration in Nordic schools

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Abstract

In this research, the design of teaching and learning with web-enabled technologies, such as iPads, in 64 one-to-one (1:1) Nordic classrooms was explored using the Digital Didactical Design (DDD) framework. DDD focuses on both teachers' activities and students' learning activities in the classroom and how web-enabled technologies are integrated into teaching, learning, and assessment. Semi-structured classroom observations were conducted to investigate how teachers apply the elements of DDD in their classroom practice, and what kinds of learning they support. The analysis resulted in three clusters: Cluster A demonstrates integration and alignment toward meaningful learning; Cluster B shows the potential for deep learning but a semi-alignment of teaching, learning, assessment, roles, and technology; and Cluster C indicates non-integration of the five elements. The findings point out that tablet integration needs the alignment of all five DDD elements to achieve meaningful learning. Pedagogy has to evolve to include new uses of the technology: it is a co-evolutionary growth of the five DDD elements together. DDD can be used by teachers for planning, self-assessment or reflective collaboration with peers and by schools to plan, document, evaluate, and rethink the interwoven pedagogy-technology relationship in tablet classrooms.

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In the last few years, school professionals have made large investments in digitalization, especially through one-to-one (1:1) programs, using mobile devices such as laptops and tablets (Bocconi, Kampylis, & Punie, 2013). Almost every student has a mobile device, requiring school professionals and teachers to rethink pedagogy and curriculum to integrate technologies in the classroom. Unlike previous technologies, mobile devices have a relatively higher acceptance rate by teachers than stationary desktop PC (Ifenthaler & Schweinbenz, 2013), they are owned by students, merge offline (i.e., in-classroom) and online (i.e., non-classroom) spaces, and dissolve classroom borders toward CrossActionSpaces (Jahnke, 2016). Online information and resources, as well as easy-to-use apps for production and communication, are available to students in the classroom, leading to new opportunities for teaching and learning within the classroom and the need for teachers to rethink their pedagogies.

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As shown by Harper and Milman (2016), the majority of previous studies of 1:1 classrooms focused mainly on a) the use of technology in classroom environments, b) effects on learner motivation, student achievement, positive effects of student engagement and collaboration (Tay, 2016). Studies focused on a small number of classrooms and followed them over time (Smith & Santori, 2015).

The purpose of this study was to identify how teachers integrated media tablets into their pedagogy, and inversely, how pedagogy was influenced by the iPad use. We focused on classrooms of a 1:1 initiative in schools in Denmark (seven schools), Sweden (seven schools), and Finland (two schools). We used classroom observations and follow-up interviews with teachers to document how teachers make use of the iPad in their classrooms. In total we analyzed 64 classrooms to determine and categorize the types of designs teachers applied in their classroom practice. This contribution focuses on the analysis of technology integration across multiple classrooms. Although we acknowledge the value of studying individual classrooms, we believe that this research is significant because it presents a framework for non-experimental research and the analysis of multiple classrooms and different types of designs used by teachers in their practice.

1. Theoretical framework: Digital Didactical Designs

Research on technology integration in school classrooms has a long tradition and has previously used frameworks such as the Substitution Augmentation Modification Redefinition (SAMR) model (Puente ruda, 2014); Technological Pedagogical Content Knowledge (TPACK; Koehler, Punya, & Yahya, 2007); and Technology Integration Matrix (TIM; Florida Center for Instructional Technology, FCIT, 2013), which have focused on stages of technology integration and the ways in which teachers make use of technological, pedagogical, and content knowledge.

For this research, we used the Digital Didactical Design (DDD) framework based on the European tradition of Didaktik (i.e., didactic), which views teaching, learning, and technology integration as a system of three components: the teacher, the student, and the content (Sensevy, 2012). DDD is useful for studying designs-in-practice that involve web-enabled technologies to gain a comprehensive picture of what goes on in individual and multiple classrooms where teachers design and implement activities using media tablets. DDD comprises five elements, which we have described in detail below: (a) teaching goals, (b) learning activities, (c) assessment, (d) social relations/roles, and (e) web-enabled technologies.

DDD is the act of modeling and forming processes in educational settings. DDD is an interplay of several elements that initiates, develops, and enhances teaching and learning processes.

The term didactic comes from the Scandinavian and German concept of Didaktik, which focuses on the relationship between content-student-teacher and emphasizes the differences between teaching activities and learning activities (Hudson, 2008; Klaflki, 1963; Lund & Hauge, 2011). Didaktik not only includes methods, but it also embraces the question of what to learn (i.e., curriculum and content); when and in what kinds of situations and locations; and how learning can be achieved (e.g., resources, institutional strategies, academic staff development; Wildt, 2007). One central component in Didaktik is the cultivation of social relationships. Without social relationships, a didactical design would be teacher led instead of learner centered. Didactic implies the science of planning and performing both teaching and learning as a social practice (Lund & Hauge, 2011), giving a form to teaching and learning.

The approach is called digital because, in an Internet-driven world, teaching practices are usually technology based but range in their support of different forms of learning in which the quantity and quality of the technology integration vary (Jahnke, Norqvist, & Olsson, 2014). Technology integration in teaching affects existing didactical designs and vice versa. Teacher adoption of technology influences and challenges the didactical design.

With the concept of design, the focus lies on specific educational components. To design is to give a form to something (Dohn & Hansen, 2014); in education, to design is to shape a focus and key points for teaching and learning as a process, usually with the aim to reach certain learning outcomes. Using the DDD approach is useful to explore the interplay and network of the design elements such as teachers’ activities and students’ activities with technologies. Additionally, based on Biggs and Tang’s (2007) work on constructive alignment that incorporates teaching goals, learning activities and assessment, these three elements were included in the DDD. Finally, the social aspect was included due to the importance of social relationships (Koole, 2009; Kukulska-Hulme & Traxler, 2013) and the dynamics of social roles (Jahnke, 2010) as design elements in educational settings. Together these five elements cover the majority of human actions in educational settings.

Listed below are the five design elements and their ideal characteristics for deep, meaningful learning:

- Teaching goals (TG) and intended learning outcomes (ILO) are clear and visible for students. The teacher communicates the relevant learning criteria so that the students know how they (the students) can make progress in their learning.
- Learning activities (LA) involve a variety of meaningful learning activities that help students achieve ILOs. Learning activities are provided, for example, in terms of assignments that help students to achieve intended learning outcomes.
- Assessment (ASM) is a process-based form of feedback and evaluation for students to receive guided reflections within the learning process for performance or skill development.
- Social relations and multiple social roles (RO) are supported. For example, teachers are experts, but they are also process mentors and learning companions, and they design learning processes in which students are not only consumers, but also producers, prosumers, meaning makers, creators, reflectors, and co-designers of learning.
• Web-enabled media tablets (TAB) are integrated in a multimodal manner to access multiple information and communication spaces that support student activities. For example, students document their learning and create student products. TABs enhance learning as a work in process. TABs are used to create, collect, and produce artifacts. Students use TABs to share, reflect on, and present their learning progress.

The second of the five DDD elements, LA, plays an integral role in DDD, and is described in greater detail in the next section.

1.1. From shallow to deeper and meaningful learning with iPads

In this research, we define learning as “an active process of constructing rather than acquiring knowledge” (Duffy & Cunningham, 1996, p. 171). The term active is related to the role of the learners as active agents and producers, or prosumers (Fischer, 2013).

Surface learning, also called shallow learning, involves activities such as learning by remembering, memorizing, and recalling content (Bloom, 1956). In this approach, students are consumers; they repeat what is in the textbook. In contrast, deep learning approaches include multiple perspectives and activities such as learning by producing and creating new ideas (Jahnke, Haertel, & Wildt, 2017). Deep learning embraces the knowledge of content and goes further toward critical reflection (Prilla, Herrmann, & Degeling, 2013) and even the creation of new content (Cook, Pachler, & Bachmair, 2011). A well-known deep learning approach is meaningful and includes learning opportunities that are authentic, active, collaborative, goal directed, and reflective (Howland, Jonassen, & Marra, 2012). Deep learning focuses on student-driven tasks and higher order thinking skills and includes assignments in which students create understanding, meaning, and new ideas. Students apply or create new knowledge to solve a problem by using online resources, information, videos, or online communities. Such a learning approach helps students expand their thinking beyond consumptive behavior and traditional reproduction of existing knowledge, moving from teaching to learning-centered classrooms (Jahnke et al., 2014).

Initial studies of DDD (Jahnke & Kumar, 2014) in Danish 1:1 classrooms indicated that the majority of the early adopter teachers (Rogers, 2003) who started to use iPads from the start of implementation in their schools created new learning goals in iPad classrooms, modified existing pedagogies, and adopted the iPad for learning-centered concepts rather than as just a teaching device. To explore in detail how teachers design their teaching and learning and what kinds of DDDs emerge in iPad classrooms, we focused our study on the following research question (RQ): How do teachers consider the five elements of DDD in their practice in iPad classrooms?

1.2. Operationalizing the DDD for analyzing classroom practice

Based on the DDD framework, we created an instrument for classroom observation that distinguishes between shallow and deeper learning and values meaningful learning in 2012. This coding scheme (as shown in Table 1 next section) was iteratively improved following use in a large number of classrooms during the initial years of this study. During the process, we applied plausibility and collaborative reflections by a team of up to five experts/researchers to ensure validity of the instrument (Patton, 1990). A five-point scale representing five possible categories was defined for each of the five DDD elements, thus focusing classroom observations on these specific parts of the teaching and learning process instead of everything that happens in the classroom.

If students could understand the Teaching Goals (TG), the highest score on the scale was assigned and if the goals were not visible to students, the lowest was assigned. This presumes that in a meaningful learning approach students would know what they would learn, thus the teaching goals would need to be visible in some form (e.g. an electronic document). Learning Activities (LA) that used the meaningful learning approach, i.e., tasks in which students were active, articulate, reflective, cooperative and authentic, and connected to the real world, were assigned the highest score, and those that did not e.g. that expected students to recall facts were assigned the lowest score. Formative or process-based Assessment (ASM) was assigned the highest score as the strongest indicator to support meaningful learning, and the lowest score was assigned when summative assessment or teacher feedback was available only at the end of the learning activity. The fourth DDD element, Social Roles and Relationships (RO), was assigned the highest score if students were active and assumed different roles such as producers, mentors or collaborators, and if the teacher assumed many different roles such as that of a process mentor and learning companion, to support students. The lowest score was assigned if the teacher assumed only the role of the expert and if students were only consumers of information. The scoring for the fifth element, web-based iPad or tablet (TAB), was informed by the Technology Integration Matrix (FCIT, 2013) where technology supports meaningful learning if it is not a substitute for pen and paper but rather is used as a collaboration tool, or for the creation of digital products. Such use was assigned the highest score whereas the lowest score was assigned if the tablet was used as a substitute for old tools or practices.

2. Research design and methods

The research presented in this article is part of a bigger research project that started in 2012. We collected data in the Nordic countries using a research design based on semi-structured classroom observations, surveys, school visits, and guided
Table 1
The digital didactical design coding scheme for studying designs-in-practice.

<table>
<thead>
<tr>
<th>DDD elements</th>
<th>Description of Coding Scheme (Scores 1–5)</th>
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<tbody>
<tr>
<td>Character of teaching goals and intended learning outcomes: clear and visible?</td>
<td>1 = Not clear, not visible, no communication about teaching goals or learning intentions; focus on content 2 = (shows indicators of 3 and 1 but not fully 3 or 1) 3 = Oral communication 4 = (shows indicators of 5 and 3 but not fully 5 or 3) 5 = Teaching goals are clear and visible for students; intended learning outcomes in forms of development of skills; a source is available where students can go and read goals/objectives; at best, co-aims of students are included, students know the criteria for learning progress (available right from the start)</td>
</tr>
<tr>
<td>Character of learning activities: toward deep learning by producing in engaged, authentic, open settings?</td>
<td>1 = Students hear what teachers read from the textbook (i.e., surface learning; e.g., memorizing, remembering/recalling, repetition of facts); theoretical problems without connecting to a real-world problem 2 = (shows indicators of 3 and 1 but not fully 3) 3 = shows signs of shallow learning and first signs of meaningful learning (i.e., active, collaborative, authentic, goal-directed, and reflective); however, students are not as engaged as in 5; they have too much time for doing other things (e.g., playing cards), they are distracted in one way or the other 4 = (shows indicators of 5 and 3 but not fully 5) 5 = Learning activities have a range from surface but a focus on deep, meaningful learning with indicators such as active, collaborative, authentic, goal directed, and reflective; students produce something, engaged classrooms, collaboration with peers; the activities are connected to the students’ world and include a real-world problem (e.g., everyday experience); a real audience, students critically reflect on existing content (e.g., evaluating/creating/making), relate knowledge to new knowledge; “organize and structure content into coherent whole” (Marton &amp; Saljo, 1976), students are engaged in producing, using the Internet, or other sources beyond the physical school walls (i.e., signs of cross-actions; e.g., communicating/learning with people who are not in the classroom)</td>
</tr>
<tr>
<td>Character of assessment: process-based?</td>
<td>1 = Feedback only at the end (i.e., summative feedback); character of the feedback is rather summative, not formative 2 = (shows indicators of 3 and 1 but not fully 3) 3 = Feedback during the class by coincidence but not only technical help; teacher only gives feedback when students ask for support; passive support 4 = (shows indicators of 5 and 3 but not fully 5) 5 = Criteria for learning progress are visible for students from the beginning of the learning process; feedback/feedback-forward at the end but mainly process-based assessment for learner’s development; a plan exists for how the teacher creates pro-assessment (i.e., formative evaluation); a range of forms such as self-assessment; peer-reflective learning, and feedback by the teacher (e.g., students document learning electronically, with a map, text), and the teacher asks them to go back and reflect</td>
</tr>
<tr>
<td>Character of social relations: multiple roles (not only consumers)?</td>
<td>1 = Teacher is in the traditional role of the expert only; students are only seen as consumers (of solving closed questions and tasks in which only one correct answer is possible) 2 = (shows indicators of 3 and 1 but not fully 3) 3 = Teacher is in one to two roles but spends majority of time as expert; teacher does not support student engagement to be active 4 = (shows indicators of 5 and 3 but not fully 5) 5 = Teacher plays different roles (e.g., expert, process mentor, learning-companion, coach); she fosters students to be in different roles such as consumers, producers, collaborators, critical reflectors; teacher engages students; teacher activates the students to change their roles; students are in several roles (e.g., teachers for their peers, finding own learning aims, creating own learning tasks); teacher supports the student reflection of roles and development of new roles</td>
</tr>
<tr>
<td>Character of web-enabled technology/tablets: for cross-actions?</td>
<td>1 = Low extent, drill and practice; students work primarily alone while using technology, not related to the real world (e.g., technology substitutes for pen and paper) – Substitution 2 = (shows indicators of 3 and 1 but not fully 3) 3 = Medium extent (e.g., new technology is substitute for existing media) – between Augmentation and Modification (Puentedura, 2014) 4 = (shows indicators of 5 and 3 but not fully 5) 5 = High extent, multimodal such as writing texts, camera app, digital paintings, using apps for collaborative creation; students construct, share, create, and publish their knowledge (to a real audience); students use online resources, actively select topics beyond the limitations of even the best school library, etc.; signs of cross-action (i.e., using the online world to solve a learning activity) – Redefinition</td>
</tr>
</tbody>
</table>
teacher interviews. Here we present the data from classroom observations in 64 classrooms across Denmark, Sweden, and Finland to describe how teachers applied DDDs in practice. Interview and survey data that dealt with other aspects of iPad integration (e.g., opinions, decisions, perceptions) are not included in this contribution.

2.1. Selection and sampling

We applied purposeful sampling (Patton, 1990) and selected schools where teachers and students had been using media tablets for more than 3 months within a 1:1 computing program. Based on Penuel’s (2006) definition of 1:1 computing with laptops, we defined a 1:1 tablet program in our sampling process as “(1) providing students with use of a mobile device loaded with contemporary applications (e.g., generic applications); (2) enabling students to access the Internet through schools’ wireless networks (WiFi);” (p. 331) and (3) focusing on using mobile devices to help complete academic tasks within the classroom and in homework assignments, tests, and presentations. Approximately 75% of the municipalities provided a central cloud computing application for the schools. Schools participating in our study used the iPad 2 or the iPad mini 1. School principals were requested to identify and contact teachers in their schools who had started to use the iPad from the beginning of the 1:1 implementation. Fifty-five teachers volunteered to participate in this research.

2.2. Countries and classrooms

In total, we observed 64 classrooms from preschool to 11th grade in five municipalities in Denmark (seven schools), Sweden (seven schools), and Finland (two schools) taught by 31% male teachers and 69% female teachers. The teacher ages ranged from 27 to 60 with the mean age of 43.2 years.

The class sizes ranged from four to 27 students with a mix of male and female students, except for one class with 27 female students and one class with four male students. The subjects taught were native language (12 classes); math (nine classes); sciences (i.e., biology, chemistry, physics; nine classes); English (six classes); religion/ethics (five classes); geography, history, social sciences, and home economics (three classes each); and others such as arts, music, and sports (one to two classes each). The observed classrooms were diverse regarding time, subjects, and topics that ranged across several lessons in contrast to lessons that focused on a specific topic. Most lessons featured one central activity, but occasionally, lessons comprised several activities.

2.3. Classroom observations with trained observers

The classroom observations that we conducted in the spring and fall of 2012, 2013, 2014, and 2015 lasted 30–90 min, with a majority lasting around 50 min. We applied a deductive process (Boyatzis, 1998) that included a partly structured classroom observation sheet, the training of the researchers to collect data, and the use of a coding scheme with clear categories for the data analysis.

All researchers had previously received training on how to use the observation protocol, and, after each observation, the team reflected on the procedure. At least two researchers conducted observations. They took notes on the structured observation sheet. With teacher and student permission, the observers documented classroom activities with photos, short videos, and time indications of when events happened. The observation involved short conversations with students and teachers to ensure meaning-making of the data and to report the data correctly.

We based the semi-structured classroom observation protocol on the five DDD elements, i.e., teaching goals, learning activities, forms of assessment, social relations/roles, and degree of media-tablet integration into the learning activities, as described earlier. The protocol also included (a) a description of the classroom from a DDD perspective (i.e., to what extent the elements were in constructive alignment); (b) how the media tablets were applied in the classroom; (c) communication patterns, social relations, and roles; (d) collaboration and forms of cooperative learning (if any); (e) feedback and assessment (e.g., when, how); (f) other issues from the observer’s point of view (e.g., if a substitute teacher taught the class, if the class was shorter than usual).

2.4. Coding and data analysis

The coding scheme for analyzing the classroom observations (Table 1) used a 5-point Likert scale based on the DDD framework to make visible the different designs-in-practice for each classroom.

We applied the coding scheme to the main learning activity in the class. We coded the other activities as initial/introductory activities or goodbye activities, which comprised 5–10 min of the entire 1–2 h lesson. Also, one of the scores in each DDD element was assigned by the observers only if the majority or most of the defined parameters of the score were represented in the data.

In summary, the coding scheme was as follows: Scores 5 and 4 in each of the five DDD elements represent classroom practices that embraced deep, meaningful learning. Scores 1 and 2 show classroom practices that focused on shallow learning such as memorizing only. Score 3 indicated classroom practices ranging between shallow and meaningful learning, but practices were not clearly one or the other.

We analyzed the data in three steps:
Step 1: applying the coding scheme to each classroom, Step 2: calculating the layers on a range from Layer 1 to Layer 5, and Step 3: grouping the five layers into three clusters.

**Step 1.** We analyzed each observed classroom using the scheme (see Table 1). We assigned a score for each of the five DDD elements for each classroom. Table 2 demonstrates an extract of DDD elements scores in classrooms.

To ensure the validity and reliability of the observation data, we used communicative validation (Bauer & Gaskell, 2000) and percentage agreements of three raters. The raters agreed on 77% of the 320 scores. In 18%, the agreement was slightly different (=/≠ 1 score), and the mean of the scores was calculated when there was a minor difference. In only 5% (n = 16) of all codes, there was little or no agreement. In these 16 scores, we used the median, not the mean. This process indicated a good agreement among different raters and confirmed the robustness of the coding scheme presented in Table 1.

**Step 2.** As a second step, based on the coding scheme, we defined five layers, where the first layer represented teacher-centered classrooms that demonstrated surface learning such as memorizing and recalling existing content. The fifth layer represented student-centered classrooms based on characteristics that support deep, meaningful learning. While applying the coding scheme from Table 1, we first looked at the five layers for each classroom, assigning the classroom data to one of the five layers as follows:

- Layer 5 was assigned when a minimum of four elements of TG, LA, ASM, RO, TAB received a 5 (as per Table 1); 4.5 was rounded up to 5.
- Layer 4 was assigned when a minimum of four elements of TG, LA, ASM, RO, TAB received a 4 (3.5 was rounded up), but when it had four elements with a 5, then the definition of Layer 5 was applied.
- Layer 3 was assigned when a minimum of four elements of TG, LA, ASM, RO, TAB received a 3 (2.5 was rounded up) or a higher score, but when it had four elements with a 4 or higher, then one of the other layer definitions was applied.
- Layer 2 was assigned when a minimum of four elements of TG, LA, ASM, RO, TAB received a 2 (1.7 was rounded up) or a higher score, but when it had four elements with a 3 or higher, then one of the other layer definitions was applied.
- Layer 1 was assigned when a minimum of four elements of TG, LA, ASM, RO, TAB received a 1 (1.5 was rounded up) or a higher score, but when it had four elements with a 2 or higher, then one of the other layer definitions was applied.

Table 3 shows the data with the applied coding scheme; the right column includes the assigned layer.

We then visualized the five layers in a pentagon for each classroom. The pentagon symbolizes the form of the teaching and learning design (i.e., a five-point scale model with five layers where the inner layer illustrates Layer 1; the second layer illustrates Layer 2; the third illustrates Layer 3; the fourth layer illustrates Layer 4; and the outer layer, the fifth layer, illustrates Layer 5) from the coding scheme illustrated in Table 1. Fig. 1 provides four examples. The more the DDD is on the outer layer, the more comprehensive the enablement is for deep, meaningful learning as coded and defined in Table 1.

### Table 2

<table>
<thead>
<tr>
<th>ID</th>
<th>Teaching Goals/Learning Outcomes</th>
<th>Learning Activities LA</th>
<th>Assessment</th>
<th>Social Relations/Roles</th>
<th>Tablets</th>
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### Table 3

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Step 3. The data indicated that the 64 classrooms were distributed over the five layers (as presented in the Findings section). To further analyze designs in the data, we clustered the five layers into three clusters. Layers 5 and 4 became Cluster A because they showed similar characteristics. Layer 3 became Cluster B because it was highly diverse within the layer. Layers 2 and 1 became Cluster C because the classrooms in these layers indicated similarities. The three clusters show the major designs for teaching and learning in iPad classrooms in this study according to teaching goals, learning activities, assessment, roles, and implementation of iPad apps. In the next section, we present the characteristics, similarities, and differences of the three clusters with regard to learning.

3. Findings

The findings in this section are presented according to the clusters (i.e., A, B, and C) that resulted from the coded DDD elements (i.e., teaching goals, learning activities, assessment, roles, and tablet integration) and layers in the 64 classrooms. Table 4 shows the distribution of the classes in three clusters as described in the next sections.

3.1. Cluster A: deep and meaningful/fully integrated all five DDD elements

Cluster A consisted of Layers 5 and 4 with a total of 23 classrooms. Figs. 2 and 3 illustrate the typical DDD form on the left and an atypical form on the right.

As is apparent in both of the pentagons on the left side, all five elements are on the outer layer. An atypical form in this cluster is pictured on the right side, where one of the four elements is not on the outer layer but tends to be an outlier to the inner layers. This was seen in three classrooms (i.e., IDs 12S, 17S, and 18S), where the teaching goal was emphasized less than learning activities, assessment, and roles; the teaching goal was not as clear as it could be from a student perspective.
Table 5 illustrates the distribution of DDD elements of classrooms in Cluster A. The table shows that the majority of the classrooms have a score of 4 or 5. Scores 4 and 5 mean that classroom practices tend toward meaningful learning, as previously described in the coding scheme of Table 1.

DDD in Cluster A classrooms had similar characteristics of teaching goals, learning activities, assessment, multiple roles, and iPad integration, as described below:

**Teaching goals.** The designs involved clear teaching goals and intended or expected learning outcomes that are visible to the students mostly in electronic format (97% aggregated from 39% Score 4 and 48% Score 5). For example, teaching goals were presented in iTunes (ID02S) and ShowBie (ID21D) or other platforms. In class 01S, the class used space on the whiteboard with the permanent heading "The goal for the lesson" highlighted in red color.

**Learning activities.** The design for learning activities promoted meaningful learning and was not limited to memorizing information. For example, in class 18D, students created new content in a chemistry class by reflecting on existing experiments and creating new ones (70% Score 5).

**Assessment.** The classrooms in this cluster designed assessment as process-based assessment (91% aggregated from 39% Score 4 and 52% Score 5). Teachers did not just help students who raised their hands, but also equally supported all students. Teachers also gave sufficient feedback during the learning process instead of at the end of a series of lessons. For example, classroom 01S and 23D used screencasting apps such as Educreation or Explain Everything. Screencasting apps record activities on the iPad with additional audio recording. The teachers asked the students to solve a mathematical problem. Students used screencasting to apply two different math strategies in a team of two or three students. The teacher’s assessment took place during the student screencasting activities, the teacher supported every group, and the peers discussed the math strategies while solving the math. Then, the students presented and discussed the digital product with the teacher and all peers with the guiding topic of discussing the pros and cons of the two different strategies.

**Roles.** The teachers actively altered the student roles and took on different roles depending on the situation (91% aggregated from 48% Score 4 and 43% Score 5). For example, in class 27D, students were in prosumer roles when they created book trailers to demonstrate how well they understood the book that they had read in previous lessons and at home. Also, teachers in Cluster A classes had in common that they did not only act as experts, but also perceived themselves to be learning companions.

**iPad integration.** Cluster A classes used content-free apps (i.e., teachers did not use subject-specific apps in which students worked individually on certain topics and studied the content). Instead, they implemented apps, such as Bookcreator, screencasting apps, Puppet Pals, Strip Designer, Popplet, Pages, and Keynote, that do not have any content. The iPad was not used as a substitute for a textbook or desktop PC; instead, the tablet was used to create new possibilities for a variety of uses:

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Layer No.</th>
<th>Classrooms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster A</td>
<td>5</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Cluster A</td>
<td>4</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Cluster B</td>
<td>3</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Cluster C</td>
<td>2</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Cluster C</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total Classrooms</td>
<td></td>
<td></td>
<td>64</td>
</tr>
</tbody>
</table>

Table 4

Classrooms in clusters.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Layer No.</th>
<th>Classrooms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster A</td>
<td>5</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Cluster A</td>
<td>4</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Cluster B</td>
<td>3</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Cluster C</td>
<td>2</td>
<td>14</td>
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</tr>
<tr>
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<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total Classrooms</td>
<td></td>
<td></td>
<td>64</td>
</tr>
</tbody>
</table>

**Fig. 2.** Cluster A classrooms – Typical form (ID21D) and atypical (ID17S), Layer 5.
learning options (88% aggregated from 44% Score 4 and 44% Score 5), which ranged from exploring topics to producing new multimodal artifacts.

The DDD of the classes in Cluster A can be summarized as having (a) clear and visible teaching goals; (b) deep, meaningful learning activities; (c) active role taking; (d) process-based assessment that helped students improve during the learning process; and (e) iPads as devices for modifying and redefining designs for teaching and learning. For example, in class 11D, students assumed active and reflective producer roles and used tablets for creating new physics experiments; students planned and conducted new experiments to show and solve a physics problem; searched the Internet for information; video-recorded their processes; discussed how to improve their failed experiments (i.e., process-based assessment); and shared final products with university students, as a real authentic audience, via the school YouTube channel. The DDD in Cluster A holistically exploited the opportunities for meaningful learning (see Table 1). The DDDs in this cluster cannot be implemented as effectively without web-enabled tablets.

3.2. Cluster B: semi-integrated

Cluster B comprised 21 classrooms, of which 13 classes formed a typical DDD form as shown on the left side in Fig. 4. DDD in these classes can be described as being in the middle of the pentagon model. Classes had a wider diversity than in Cluster A because eight classes had atypical forms. Three had atypical forms with a stronger tablet integration (IDs 25D, 03S, 28D), and five had anomalies on several such as learning activities and teaching goals (IDs 08F, 15S); teaching goals and assessment (ID13S); roles (ID05S); and iPads (ID27D), as shown in the right pentagon in Fig. 4.

Table 6 shows the distribution of the five DDD elements in 21 classrooms in Cluster B. Whereas classrooms in Cluster A had an emphasis on Scores 4 and 5, classrooms in Cluster B tended toward Score 3 in the middle. Unlike Cluster A, Cluster B was more heterogeneous with a broader distribution. Score 3, as previously described in Table 1, indicates that meaningful learning had not been achieved. In 13 classrooms, there was a tendency toward Score 4, and in eight classrooms, there was a tendency toward Score 2.

DDD in Cluster B classrooms had the following characteristics in common: **Teaching goals.** Teaching goals were clear to some extent but were only orally communicated to the students and not digitally accessible to them as in Cluster A (48% Score 3).
Learning activities. Learning activities fell between shallow and meaningful learning with a stronger tendency toward meaningful learning (53% Score 4). Students were not as engaged as in Cluster A classes and engaged in off-topic activities (e.g., playing cards).

Assessment. Classes did not include process-based feedback. The teacher gave random feedback that was not equally distributed, and the teacher gave feedback when students asked for support or when they raised their hands (71% Score 3).

Roles. Students were largely in passive consumer roles, and the teacher did not plan for students to be in active producer roles (52% Score 3). Teachers spent the majority of the classroom time playing the role of experts, but from time to time, they took on other roles such as mentors, whereas teachers and learners took on multiple roles in Cluster A classrooms.

iPad integration. The iPad in Cluster B acted as a substitution for a digital writing machine such as a laptop or desktop PC in 43% (Score 3) of the classrooms, and augmented learning through the iPad device was not used to fully exploit the benefits of a web-enabled small flexible device toward a redefinition of learning.

For example, in a Grade 3 classroom (ID16D), students watched a comic movie about Nordic gods. The student task was to then individually collect information about Nordic Gods and put them into Popplet, a mind-map app. The teaching goals were not clear because they were not documented, visible, or communicated in the classroom. Students were not engaged and were observed to be chatting off topic. The teacher gave feedback on the mind maps only if students asked for help. The teacher did not plan for equally giving formative feedback in a systematic way for all students. Students were mainly in consumer roles watching a movie, and during the activity of collecting information and creating something in Popplet, they became more active. The teacher spent the majority of the classroom time as content expert and occasionally as technology helper when there was a problem with the mind-map app. This classroom was representative of Cluster B because the classroom practice tended toward meaningful learning with tablets; the teacher made minor changes (assumably driven by the iPad) but also stuck to traditional roles for teaching and learning.

The DDDs in Cluster B were perceived to be in the middle between the emergent classrooms in Cluster A and the traditional classrooms in Cluster C (described in the next section). Small incremental changes toward meaningful learning were visible, but it was not an entirely new coherent whole, as previously shown in Cluster A.

3.3. Cluster C: shallow or no integration

Cluster C consisted of 20 iPad classrooms from Layers 2 and 1. Fig. 5 illustrates Cluster C classes from Layer 2, and Fig. 6 presents examples of classes from Layer 1. The typical shape is illustrated on the left side while the atypical is on the right.
Cluster C included 13 atypical shapes. Seven of the atypical shapes showed similarities in iPad usage in combination with assessment (IDs 11S, 05F, 01D) and learning activities (IDs 23S, 09F, 06S, 03D).

Table 7 shows classroom practices from the view of the five DDD elements. Cluster C is more heterogeneous than Cluster B; the majority of the DDD elements range from Scores 1 to 3. Classroom practices tended toward Scores 2 and 1 that represent shallow learning and no clear teaching goals. The data indicate differences in classroom practices in Cluster B and C.

Classrooms in Cluster C followed a traditional didactic design approach that did not exploit the potential of web-enabled tablets for learning by making or producing and no alignment of the five DDD elements toward deeper learning.

Teaching goals. In Cluster C, teaching goals were neither clear to the students nor documented (65% aggregated from 45% Score 1 and 20% Score 2).

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Note. Scores 1 to 5 are presented in detail in the coding scheme, as previously shown in Table 1.
Learning activities. Learning activities were mainly designed in the Instruction-Response-Evaluation mode (Mehan, 1979) in which a single question from the teacher was followed by a right student answer (35% aggregated from 10% Score 1 and 25% Score 2). Further, all students were often found not to interact with each other or create something, but they completed activities in a more uniform manner. Forty-five percent of classrooms showed initial signs of meaningful learning in which students were not only consumers, but were also active.

Assessment. Assessment with no formative intention or process enhancement was observed (50% aggregated from 25% Score 1 and 25% Score 2). Thirty-five percent of the classrooms showed first signs of formative assessment activities.

Roles. The classes mainly supported single student roles and not multiple prosumer roles. Teachers were experts and represented knowledge-givers, and students were consumers and passive learners who memorized information (75% aggregated from 30% Score 1 and 45% Score 2). For example, teachers created learning activities in which the right answer had to be found, but the students were not allowed to use the iPads as a supporting tool to find the answer. Observers made notes that students looked irritated (14D).

iPod integration. The iPod was often used as a substitute for a writing machine such as a stationary PC (30% Score 3). The benefit of using an app for a certain learning activity was unclear (40% aggregated from 20% Score 1 and 20% Score 2). For example, Popplet is a mind-map tool for brainstorming, and students were told to use this app to write a chronological order (timeline) of their activities during their summer holidays (ID19D, similar ID09D). The students added their activities into the app but did not create a chronological order rather a word cloud. Students needed different instructions for compiling the correct timeline, or could have used other apps.

In most of the Cluster C classrooms, the iPod was used as a substitute for a desktop PC (e.g., for the creation of a simple keynote presentation, watching videos [ID01D]; learning in text-based formats [ID06F]; and using Quizlet apps for language learning [ID26D]). Atypical classrooms used, for example, Kahoot for shallow learning such as memorizing with multiply choices in a game format (ID05F).

DDD can be called a traditional didactic approach in which the potential of iPads has not been exploited for deeper learning. As the observers noted for the class 14D, “The lesson design did not use the possibilities of the iPad...” (field notes 14D, August 12, 2012). In this class, students wrote interview questions on the iPads but did not share, discuss, or annotate. Instead, the teacher asked them to print the questions for homework (ID14D). Students appeared irritated, as though they saw that the iPad is useful for solving assignments but were not allowed to use it in such a way.

4. Discussion

The purpose of this research was to explore DDDs in iPod classrooms. Our analysis of classroom observations in 64 1:1 media tablet classrooms in Nordic schools points to a range of DDD. Teachers demonstrated a different emphasis on the five design elements of DDD, resulting in designs that we categorized into three clusters. In the following sections, we discuss the diversity of DDDs in Clusters A, B, and C and implications for 1:1 media tablet classrooms.

4.1. Digital Didactical Designs with iPads

DDDs that exploit the five design elements of the DDD framework shape a new coherent whole that creates deep, meaningful learning opportunities. In such designs, the teachers (a) perceive the classroom as a dynamic communication space and create new designs for learning involving online settings (e.g., searching for information online, creating and sharing digital student products); (b) perceive classrooms as places for reflective learning, and they support reflection by creating assignments that merge online and offline spaces; and (c) holistically exploit the opportunities for supporting deep, meaningful learning through process-based assessment. Teachers who created such DDDs (i.e., Cluster A in this study) constructively aligned all five design elements into a coherent new whole. They had in common that they created learning opportunities that went from a traditional course-based learning approach to student-centered meaningful learning experiences. Typically, teachers set tasks or created activities that enabled learning toward different possible solutions, where no correct answer existed. They created designs for learning focusing on knowledge production in groups, and the iPad helped to make the students’ learning process visible and provided access to communication spaces beyond the school walls. DDDs in Cluster A indicate teachers connected the types of learning supported by the technology with new forms of pedagogy (TG, LA, ASM, RO) e.g., new student activities, new forms of process-based assessment through the iPad, new roles for teachers and students, indicating a co-evolutionary growth of both pedagogy and technology together.

DDDs for meaningful learning make learning visible in multiple formats. In Cluster A of this study, the students used different apps to share their learning processes and learn from each other via co-located communication spaces. The assignments were created in a way that the students could choose how to make their learning visible; they did not only choose to write. The teachers also encouraged students to create other products such as digital paintings, digital stories, comics, movies, and podcasts. Often, the teachers used apps that were originally not made for school purposes (e.g., Bookcreator, Puppetpals, Popplet, Stripdesigner, Comicbook).

We termed 33% of such designs (Cluster B) semi-integrated because they did not fully exploit the new learning possibilities of media tablets and Internet access in the classrooms and the remaining 31% shallow or not integrated because they did not demonstrate elements that contribute to meaningful learning. In these designs, teachers attempted to create new interwoven forms of pedagogy and technology but focused on one or two DDD elements and did not change the others. For example, the
iPad was used in a unique way in an outdoor activity using the camera, however, the learning goals were not clear to the students or the assessment was not designed for meaningful learning rather for shallow learning of recalling facts. Teachers in Cluster B and C attempted to integrate the iPad and apps, but they did not quite achieve a redesign of teaching and learning and often used the QAC mode (i.e., teacher’s single Question, student Answers, teacher says Correct or Wrong). In some cases, it was obvious to the observers that students saw that the iPad could be used for Internet searches or to learn differently, but the design of the learning activities and their consumer roles limited their actions. The relationship of the DDD elements, learning activities and roles, were not aligned. These DDDs did not exploit the potential of web-enabled technologies and did not completely rethink the didactical design to make sense of the new forms of online or co-located communication spaces.

Another difference between the clusters was that tablets in Cluster A classrooms became student devices for learning, whereas in Cluster C classrooms the tablet was a teacher device, teachers used the tablet for distributing information or controlling the smart board.

This was particularly noticeable with iPad integration and learning activities in 16 classrooms across the two clusters B and C that were found to strive toward deeper learning activities and tablet integration, but they neglected or emphasized the other elements less (TG, ASM, RO), namely, teaching goals were not visible; assessment was rather summative; and low or no support of role dynamics. Fig. 5 gives an example of this pattern: the atypical ID23S classroom on the right side. In these 16 designs, the tablet was a starting point for teachers to design toward meaningful learning and the tablet was used to support this new form of learning. However, role dynamics, teaching and learning goals, and process-based assessment were not changed in the design—the interplay between all the five elements was not yet aligned as a new coherent whole. To achieve meaningful learning, not only learning activities must be changed to open assignments and reflective production but also teaching goals and assessment need adjustments, accompanied by changes in the teacher and student roles as mentors, learning companions, and producers of meaningful knowledge.

4.2. Implications for schools and 1:1 tablet classrooms

Our research can help schools and teachers to reflect on and evaluate current teaching and learning practices in 1:1 tablet classrooms. The DDD can be used as a planning tool for deep and meaningful learning in online spaces where students are active and solve authentic tasks related to the real world. The DDD can provide schools with a framework for guiding discussions about curriculum changes in tablet classrooms and the coding scheme we presented can be used for evaluating the changes. This mature DDD coding scheme can be used by teachers as a self-assessment tool, or for collaborative reflection with their peers to observe and discuss changes they make in tablet classrooms and the impact of those changes on student learning. It also can be used by other researchers wishing to study 1:1 media tablet classrooms according to DDD or for teacher professional development.

4.3. Implications for future research

The DDD framework provides a foundation for planning and implementing a shift from teaching-centered to learning-centered approaches. Our focus in this study was the holistic design of the five DDD elements in iPad classrooms; we did not analyze the data for the teaching of a particular subject or focus on specific designs at any grade level. These are areas of future research that could be conducted using our theoretical framework and coding scheme. Possibly, DDD and teachers’ rethinking of teaching and learning to some degree are dependent on the subject and the type of content being taught. Conducting a longitudinal study, for instance, to follow a group of teachers throughout the year to observe the ways in which their designs vary depending on what part of the curriculum they are teaching at a certain point in time would be valuable.

Additionally, our explanation of the methodology used—a coding scheme, scores, and layers—can be adapted by researchers wishing to study other types of learning or other learning outcomes. They can adapt our methods, especially this coding scheme, for their purposes and define the five elements accordingly.

5. Limitations of the research

DDD is an activity-driven social and sociotechnical design process and involves different actors and agents on different levels (Lund & Hauge, 2011). This research focused on the classroom level of the process, not on school or policy levels. Further, this research was conducted in 1:1 iPad classrooms, and the affordances of other media tablets may be different. We also did not consider the ways in which students may be using the iPads outside of the classroom but focused on the DDD within the classroom.

The sample of teachers whose classrooms were visited in this study consisted of those who began using media tablets when 1:1 initiatives were introduced in Nordic schools. This research, thus, only includes 1:1 classrooms where (a) teachers attempted to integrate the iPads into their teaching and learning processes and (b) were also willing to share these designs-in-practice with us. Moreover, the schools had continual Internet access, making it possible for teachers to use the web-enabled features of the media tablets. These factors may not always exist at other sites and should be taken into consideration by others attempting to conduct similar studies.
6. Conclusion

The purpose of our study was to explore DDD in technology-rich classrooms in Nordic countries. We identified DDD, its contribution to meaningful learning, and the interplay of the DDD elements. We found that teachers in our study integrated the elements of teaching, learning, assessment, roles, and technologies in different ways; used different types of learning activities and apps; and redesigned teaching and learning when offline and online worlds merged in the classroom. As web-enabled media tables become increasingly prevalent in schools, several areas for consideration emerge with curriculum design and teacher development.

When teachers redesign teaching and learning toward deep, meaningful learning with iPads, their roles change, their students' roles change, classroom activities involve the use of available online and offline resources, and students learn differently. Such changes may conflict with expectations of assessment in the curriculum, standardized testing, and even the basic assumptions held in a school or educational system about what constitutes learning and assessment of that learning. Thus, 1:1 implementations require larger considerations of curriculum, strategy, and alignment with assessment in schools. Research into technology integration in these new contexts must also explore the use of new frameworks that may be better suited to the merging of online and offline spaces. In this study, we used DDD as an approach to studying designs-in-practice. As classrooms increasingly become creative spaces for learning with the inclusion of media tablets and laptops, such research is needed in multiple contexts to refine existing frameworks and models of teaching and learning and develop new ones that can guide teachers and schools in the digital age.

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