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Does ICT contribute to powerful learning environments in primary education?

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Abstract

In powerful learning environments, rich contexts and authentic tasks are presented to pupils. Active, autonomous and co-operative learning is stimulated, and the curriculum is adapted to the needs and capabilities of individual pupils. In this study, the characteristics of learning environments and the contribution of ICT to learning environments were investigated. A questionnaire was completed by 331 teachers in the highest grade of primary education. Results show that many teachers apply several elements of powerful learning environments in their classes. This especially goes for the presentation of authentic tasks and the fostering of active and autonomous learning. However, the methods employed by teachers to adapt education to the needs and abilities of individual pupils proved quite limited. The use of ICT in general merely showed characteristics of traditional approaches to learning. Chances of using open-ended ICT applications, which are expected to contribute to the power of learning environments, were greater with teachers who created powerful learning environments for their pupils, and when there were more computers available to pupils. In addition, teachers' views with regard to the contribution of ICT to active and autonomous learning, teachers' skills in using ICT, and the teacher's gender appeared to be relevant background variables in this respect.

Keywords: Elementary education; Media in education; Teaching/learning strategies

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1. Introduction

1.1. The need for powerful learning environments

Education should offer conditions needed to optimize learning and promote the transfer of knowledge and skills. Authenticity is an important issue which should be addressed in the design and development of learning environments (Collins, 1996). Learning environments need to reflect the potential uses of knowledge that pupils are expected to master, in order to prevent the acquired knowledge from becoming inert (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Duffy & Knuth, 1990). Rich contexts and tasks that are as authentic as possible should be provided by presenting links to the world outside school. In addition, teachers should stimulate pupils to engage in active knowledge construction. This calls for open-ended learning environments instead of learning environments which focus on a mere transmission of facts (Collins, 1996; Hannafin, Hall, Land, & Hill, 1994; Jonassen, Peck, & Wilson, 1999). Co-operation and interaction in the classroom environment are important in order to foster the acquisition of learning skills, problem solving skills, and social relations (Bennett & Dunne, 1994; Slavin, 1995; Susman, 1998). Finally, since classes are of mixed ability, differentiation is considered to be one of the key criteria for effective classroom practice (Bearne, 1996; Kerry & Kerry, 1997; Wang, 1990). Teachers are expected to adapt the educational setting to the needs and capabilities of the individual pupils.

Powerful learning environments foster optimal learning processes by reflecting the key aspects outlined above. In conclusion, the following four main characteristics of powerful learning environments are distinguished:

- rich contexts and tasks that are as authentic as possible are provided to present links to the world outside school;
- active and independent learning is stimulated;
- co-operative learning is stimulated;
- the curriculum is adapted to the needs and capabilities of the individual pupils.

1.2. The potential of ICT in powerful learning environments

ICT may contribute to creating powerful learning environments in numerous ways. ICT provides opportunities to access an abundance of information using multiple information resources and viewing information from multiple perspectives, thus fostering the authenticity of learning environments. ICT may also make complex processes easier to understand through simulations that, again, contribute to authentic learning environments. Thus, ICT may function as a facilitator of active learning and higher-order thinking (Alexander, 1999; Jonassen, 1999). The use of ICT may foster co-operative learning and reflection about the content (Susman, 1998). Furthermore, ICT may serve as a tool to curriculum differentiation, providing opportunities for adapting the learning content and tasks to the needs and capabilities of each individual pupil and by providing tailored feedback (Mooij, 1999; Smeets & Mooij, 2001).

As Stoddart and Niederhauser (1993) point out, ICT may fit into a spectrum of instructional approaches, varying from traditional to innovative. Niederhauser and Stoddart (2001) distinguish

two main types of software use in education: skill-based transmission software, and open-ended constructivist software. Typically, skill-based software aims at enhancing pupils' skills by administering drill and practice exercises. Open-ended software may serve as a tool for helping learners build knowledge (Jonassen, 1999; Squires, 1999). This type of ICT use may be expected to contribute especially to powerful learning environments.

However, research shows that the focus in schools in general is on traditional, skill-based ICT use (Chalkley & Nicholas, 1997; Richardson, 1997; Smeets & Mooij, 2001; Williams, Coles, Wilson, Richardson, & Tuson, 2000). In addition, in a recent study of the impact of ICT on pupil attainment, in which 60 schools were involved, it was found that the proportion of lessons involving ICT was generally small. Some positive relations between the amount of ICT use and pupil attainment were found, but the relationship found was not consistent over all subjects at all key stages. Therefore, the authors assume that the type of use is important (Harrison et al., 2002).

Obviously, the selection and use of software by teachers can have a significant impact on the learning environment. In this respect, the teacher's skills with regard to ICT use play an important role (Smeets et al., 1999; Veen, 1995). Another aspect which may of course influence the use of ICT is access to technology (Kennewell, Parkinson, & Tanner, 2000; OTA, 1995). This refers not only to the number of computers, but also to the placement of the equipment, e.g. in the classroom or in a computer room. Kennewell et al. (2000) feel it is essential that computers be placed in the classroom, in order to maximize the opportunities for curriculum activity. These authors state that the number of computers available is of less significance.

In addition, teachers' pedagogical perspectives and their views on how ICT can contribute to the learning environment may play an important role in their actual use of ICT in the classroom (Drenoyanni & Selwood, 1998; Higgins & Moseley, 2001; Hokanson & Hooper, 2000; Niederhauser & Stoddart, 2001). However, Sinko and Lehtinen (1999) point out that often there is a conflict between approving of certain principles with regard to learning environment design and development by teachers, and the actual implementation of these principles in classrooms. The shift towards more pupil-centred learning environments requires teachers to create an intellectual environment in which knowledge is acquired. The teacher is no longer the all-knowing controller of activities. At times, she or he is learner and explorer with the pupils. In particular, this applies to open-ended learning arrangements (Hannafin & Savenye, 1993; Keeler, 1996).

Niederhauser and Stoddart (2001) found that teachers who adhered to traditional transmission approaches to instruction, tended to prefer skill-based software, whereas most teachers who supported constructivist views of teaching and learning, used skill-based as well as open-ended software. This conclusion is consistent with observations made by Pisapia (1994a) that in exemplary classrooms teachers may use resources in different ways, such as drill and practice exercises, simulations, problem-solving activities, and productivity tools. A characteristic of these classrooms is that pupil use of learning technologies is woven integrally into the patterns of teaching. Teacher-centred teachers, on the other hand, tend to use traditional instructional methods, and to regard learning technologies mainly as basic skill reinforcers, motivators, or 'special treats' (Pisapia, 1994b). Demetriadis et al. (2003) concluded that teachers are strongly oriented towards fulfilling the established school instructional targets. As a result of this, according to these authors, teachers tend to ignore innovative learning activities because they are disturbing.

1.3. Research questions

The goal of the present study was to gain more insight into the characteristics of learning environments in the highest grade of primary education, and in the use of ICT in these learning environments. The study was funded by the National Organization for Scientific Research in the Netherlands (NWO). The focus was on answering three research questions:

(1) What are the characteristics of learning environments in the highest grade of primary education?
(2) What is the contribution of ICT to the learning environment?
(3) What factors influence the use of ICT in the learning environment?

2. Method

2.1. Instrument

A survey was carried out among teachers in grade 8 of Dutch primary education (with pupils aged 11–12). A questionnaire was developed which included three sections: teacher and class variables, characteristics of the learning environment, and the use of ICT.

Teacher and class variables included the teacher's gender, the number of years of experience as a teacher, the teacher's self-rating of skills in the use of ICT, the number of pupils in class, the number of computers available to pupils during the lessons, and the placement of computers in the classroom or in a computer room. In addition, 9 items with regard to teachers' views on the contribution of ICT to teaching and learning were included. These Likert items consisted of four-point scales ranging from 'no or hardly any contribution' to a 'substantial contribution'.

The items that referred to characteristics of the learning environment addressed the stimulating of active, autonomous and co-operative learning in mother-tongue teaching and arithmetic instruction (5 Likert items), curriculum differentiation (7 Likert items), and the authenticity of the learning tasks (5 Likert items). The items consisted of four-point scales ranging from 'never or hardly ever' to 'often'.

Finally, items with regard to the use of ICT addressed the frequency of ICT use during classes, as well as the frequency of use of ten specified types of ICT applications. In addition, the grouping of pupils during ICT-related activities (3 Likert items), and the use of ICT in curriculum differentiation (5 Likert items) were addressed. All items were Likert items, consisting of four-point scales ranging from 'never' to 'often'. Apart from this, the amount of time that on average is allocated per pupil per week for using ICT was inquired.

2.2. Subjects

A random sample of 773 was drawn from the population of 7041 primary schools. In each school, the head-teacher was requested to pass on the questionnaire to the teacher in grade 8. In case there were more grade 8 teachers present, the head teacher was requested to choose the teacher who uses ICT most frequently during her/his lessons. The questionnaire was completed by 331 teachers, which accounts for 43 per cent of the sample. The large majority of the participating

teachers were male (84 per cent). The average number of years of experience in education was nearly 21 (in a range from 1 to 44). Three out of four teachers felt that their skills in the use of computers were good (28 per cent) or quite good (47 per cent).

2.3. Analyses

For the Likert items, α-scale construction was carried out by applying principal component analyses and by calculating Cronbach α-scores. Items that reduced the α-score were excluded from the scales. Subsequently, mean scores per scale were calculated. In order to assess the influence of background variables on the design and development of the learning environment as well as on the use of ICT, Pearson correlation coefficients were calculated and multiple regression analyses were carried out.

3. Results

3.1. Characteristics of the learning environment

Table 1 lists the items in the scale 'Stimulating autonomous and co-operative learning'. These items refer to usual classroom practice in arithmetic teaching and mother-tongue instruction. A large majority of teachers stated that they often stimulate their pupils to work autonomously, and they often pay special attention to problem-solving strategies. About half of the teachers often refer to the application of knowledge, and stimulate pupils to discuss the learning content. One in three teachers often stimulates her/his pupils to find things out on their own.

Table 2 shows seven possible ways of adapting the curriculum to pupils' individual needs and capabilities. The table shows that curriculum differentiation in primary education mainly consists of presenting remediation learning materials to low-achieving pupils and of presenting enrichment materials to high-ability pupils.

Table 1
Stimulating autonomous and co-operative learning

	Never/hardly ever	Occasionally	Regularly	Often
Stimulating pupils to work autonomously	0%	2%	18%	80%
Paying special attention to problem solving strategies	0%	7%	28%	65%
Referring to the application of the acquired knowledge and skills	1%	13%	38%	48%
Stimulating pupils to discuss the learning content together	1%	18%	32%	49%
Stimulating pupils to find out things on their own or together with fellow pupils	1%	25%	42%	33%

Cronbach $\alpha = 0.69$; 5 items; four-point Likert scale (1–4); mean = 3.41; standard deviation = 0.46; $N = 328$.

Table 2
Curriculum differentiation

	Never/hardly ever	Occasionally	Regularly	Often
Additional learning materials or tasks for advanced pupils	0%	18%	48%	34%
Remediating learning materials or tasks for slower pupils	0%	19%	48%	34%
More or longer exercising for slower pupils	7%	41%	41%	11%
Different activities for different pupils	7%	37%	39%	17%
Different learning content for different pupils	12%	46%	29%	13%
Allowing pupils to choose learning tasks themselves	18%	44%	30%	7%
Allowing pupils to choose learning contents themselves	39%	48%	10%	3%

Cronbach $\alpha = 0.80$; 7 items; four-point Likert scale (1–4); mean = 2.57; standard deviation = 0.53; $N = 325$.

Table 3
Authenticity of the learning environment

	Never/hardly ever	Occasionally	Regularly	Often
Using authentic texts	5%	64%	24%	8%
Referring to the application of the acquired knowledge and skills outside school	2%	26%	55%	18%
Discussing recent events during the lesson	0%	12%	50%	38%
Paying special attention to information handling skills	1%	29%	53%	17%

Cronbach $\alpha = 0.72$; 4 items; four-point Likert scale (1–4); mean = 2.84; standard deviation = 0.51; $N = 330$.

Teachers try to create authentic learning environments by frequently discussing recent events during the lessons, by referring to the application of the acquired knowledge and skills outside school and by paying special attention to information-handling skills (see Table 3).

The items presented in Tables 1–3 constitute a scale which provides an indication of the 'power' of the learning environment. After the deletion of 2 of the items, reliability analysis resulted in a Cronbach α of 0.83. The scale consists of the following items:

- Stimulating pupils to work autonomously;
- Paying special attention to problem solving strategies;
- Stimulating pupils to discuss the learning content together;
- Stimulating pupils to find out things on their own or together with fellow pupils;
- Providing additional learning materials or tasks for advanced pupils;
- Providing remediating learning materials or tasks for slower pupils;
- Providing different activities for different pupils;
- Providing different learning content for different pupils;
- Allowing pupils to choose learning tasks themselves;

- Allowing pupils to choose learning contents themselves;
- Using authentic texts;
- Referring to the application of the acquired knowledge and skills outside school;
- Discussing recent events during the lesson;
- Paying special attention to information handling skills.

The power of the learning environment is expressed by a score on a four-point scale (from 1 = 'Low' to 4 = 'High'). The mean score in this sample was 2.89 (SD = 0.40; range from 1.64 to 4.00).

3.2. Teachers' views

In the questionnaire the teachers' views on the contribution of ICT to the learning environment in their classes were addressed. The items that were included in the questionnaire were found to consist of two scales. The first scale referred to teachers' views on the contribution of ICT to independent pupil learning and curriculum differentiation. In general, teachers appeared to value this contribution as quite large. The second scale referred to teachers' views on the contribution of ICT to active and autonomous learning. The majority of teachers felt ICT provides a slight or fair contribution to these types of pupil learning (see Table 4).

3.3. ICT use

The large majority of teachers surveyed (93 per cent) used ICT in their lessons. About 50 per cent used ICT quite often (37 per cent) or often (16 per cent); 41 per cent made occasional use of ICT. According to the teachers who used ICT in their class, pupils on average spent 55 min a week

Table 4
Teachers' views on the contribution of ICT to the learning environment

	No/hardly any contribution	Slight contribution	Fair contribution	Substantial contribution
I: with regard to independent pupil learning and differentiation				
Providing pupils with opportunities to practice for themselves	1%	7%	47%	45%
Providing pupils with opportunities to process information independently	6%	19%	44%	31%
Adapting the curriculum to the individual pupils' needs and abilities	7%	31%	41%	21%
II: with regard to active and autonomous learning				
Stimulating active learning	6%	23%	51%	21%
Supporting pupils in directing their own learning	11%	40%	39%	10%
Supporting problem solving	16%	37%	37%	10%
Supporting co-operative learning	19%	39%	34%	8%

I: Cronbach $\alpha = 0.71$; 3 items; four-point Likert scale (1–4); mean = 3.04; standard deviation = 0.64; $N = 308$.
II: Cronbach $\alpha = 0.81$; 4 items; four-point Likert scale (1–4); mean = 2.53; standard deviation = 0.68; $N = 308$.

Table 5
Type of ICT use

	Never	Occasionally	Regularly	Often
I: Skill-based applications				
Drill and practice in mother tongue	11%	36%	30%	23%
Drill and practice in arithmetic	14%	41%	27%	19%
Drill and practice in topography	17%	38%	26%	19%
II: Open-ended applications				
Word processing	20%	42%	23%	16%
Drawing	40%	44%	13%	2%
Encyclopaedias (CD-ROM)	59%	23%	13%	6%
Searching information on the World Wide Web	74%	18%	6%	2%
Simulations	75%	23%	2%	0%
Dictionaries (CD-ROM)	82%	15%	3%	1%
E-mail	84%	13%	3%	0%

I: Cronbach $\alpha = 0.65$; 3 items; four-point Likert scale (1–4); mean = 2.54; standard deviation = 0.74; $N = 330$.
II: Cronbach $\alpha = 0.68$; 7 items; four-point Likert scale (1–4); mean = 1.55; standard deviation = 0.42; $N = 330$.

at the computer. The ten items with regard to the use of ICT in the classroom consisted of two α-scales. These were labelled 'Skill-based use' and 'Open-ended use', respectively (see Table 5).

The table shows that skill-based software is used substantially more often than open-ended software. With respect to open-ended software, word processing is the application that is used substantially more often than the other types of applications listed.

Table 6 provides information about the use of ICT in curriculum differentiation. Teachers especially used ICT for presenting learning materials or tasks to slower pupils for remediation. From the teachers who processed the questionnaire 56 per cent frequently did so. ICT was used to a lesser extent for enabling slower pupils to exercise more or longer, for presenting additional learning materials or tasks to advanced pupils, or for presenting different activities to different pupils.

Table 6
The use of ICT in curriculum differentiation

	Never/hardly ever	Occasionally	Regularly	Often
Using ICT for presenting additional learning materials or tasks for advanced pupils	16%	44%	27%	12%
Using ICT for presenting remediating learning materials or tasks to slower pupils	10%	33%	37%	19%
Using ICT for more or longer exercising for slower pupils	16%	43%	28%	11%
Using ICT for presenting different activities to different pupils	19%	39%	30%	11%

Cronbach $\alpha = 0.78$; 4 items; four-point Likert scale (1–4); mean = 2.41; standard deviation = 0.73; $N = 325$.

Table 7
Grouping of pupils during ICT-related activities

	Never/hardly ever	Occasionally	Regularly	Often
Pupils work individually	1%	20%	59%	20%
Pupils work in pairs	8%	57%	34%	1%
Pupils work in small groups	76%	21%	4%	0%

Table 7 shows that when pupils are using ICT, they usually work alone. The use of ICT to support co-operative learning was employed considerably less frequently. If pupils work together at the computer, they usually do so in pairs, whereas working in small groups is applied to a much lesser extent.

3.4. Variables that influence the type of ICT use

Multiple regression analyses were carried out to assess the influence of background variables on the frequency of skill-based and open-ended use of ICT, respectively (see Tables 8 and 9). The following independent variables were processed:

- Teacher variables: teacher's gender; number of years of experience as a teacher; the teacher's skills in the use of ICT, as rated by the teachers themselves.
- Class variables: number of pupils in class; the pupil-computer ratio; availability of a computer room.

Table 8
Variables that influence skill-based use of ICT; results from a multiple regression analysis

	B	SE	β	*p*
Intercept	0.738	0.345		
Teacher's views on the contribution of ICT to independent learning and curriculum differentiation	0.234	0.071	0.231	0.001
Teacher's skills in the use of ICT	0.137	0.043	0.184	0.001
Computer room available	−0.240	0.098	−0.149	0.015
Number of pupils in class	0.014	0.006	0.134	0.019

Table 9
Variables that influence open-ended use of ICT; results from a multiple regression analysis

	B	SE	β	*p*
Intercept	0.604	0.214		
Power of the learning environment	0.219	0.059	0.216	0.000
Pupil–computer ratio	−0.014	0.004	−0.203	0.001
Teacher's views on the contribution of ICT to active and autonomous learning	0.102	0.041	0.167	0.013
Teacher's skills in the use of ICT	0.064	0.026	0.135	0.016
Teacher's gender	−0.152	0.063	−0.134	0.016

- Teachers' views on the contribution of ICT to the learning environment: with regard to independent learning and curriculum differentiation (α-scale), and with regard to active and autonomous learning (α-scale).
- Power of the learning environment (α-scale).

Results from the regression analyses show that teachers who were more confident about their skills in using ICT, were more likely to use skill-based ICT applications in their class. In addition, skill-based use of ICT was favoured by teachers who felt that ICT contributes to independent learning and curriculum differentiation. Apart from this, more skill-based use of ICT was noted in classes with a larger number of pupils. Finally, the presence of a computer room appeared to decrease the amount of skill-based ICT use (see Table 8). These variables accounted for 19 per cent of the variance in the dependent variable.

Open-ended applications of ICT were more likely to appear with teachers who create powerful learning environments, and when there were more computers available for pupils. In addition, the use of open-ended applications was fostered when teachers felt that ICT contributes to active and autonomous learning, and when teachers were more confident about their skills in using ICT. Apart from this, female teachers appeared to less favour the use of open-ended ICT applications, as compared to their male colleagues (see Table 9). These variables accounted for 24.4 per cent of the variance in the dependent variable.

A significant, but not very strong relationship was found between the power of the learning environment and the use of ICT to support co-operative learning (Pearson $r = 0.16$; $p < 0.01$). A significant relationship was also found between the power of the learning environment and the use of ICT for curriculum differentiation (Pearson $r = 0.40$; $p < 0.001$).

4. Discussion

In this study, four characteristics of powerful learning environments were distinguished. In powerful learning environments rich contexts and authentic tasks are presented to pupils, active and autonomous learning is stimulated, co-operative learning is stimulated, and the curriculum is adapted to the needs and capabilities of the individual pupils. The results of this study show that teachers in the highest grade of primary education apply several strategies to foster optimal learning processes. This especially relates to the presentation of authentic tasks and the fostering of active and autonomous learning. The methods employed by teachers to adapt education to the needs and abilities of the individual pupils, however, seemed quite limited.

Most teachers valued the potential contribution of ICT to the learning environment as quite large. This especially applied to the use of ICT as a means to contribute to independent pupil learning and curriculum differentiation. However, even though 93 per cent of the teachers who filled out the questionnaire applied ICT in their classes, the use of ICT in general remained disappointing, the emphasis being on skill-based applications that fit into traditional views of teaching and learning. This finding matches findings from other studies. Only a minority of teachers used open-ended ICT applications that can stimulate the pupils' information-processing skills, that support co-operative learning, and that can contribute to bridging the gap between

school learning and the 'real world'. In addition, with respect to curriculum differentiation, the emphasis in ICT use was on remediating tasks for low-achieving pupils, whilst the potential of stimulating high-achieving pupils by means of ICT was neglected by many teachers. Apart from this, whereas four out of ten teachers felt that ICT provides a fair or a substantial contribution to co-operative learning, the use of ICT for supporting co-operative learning was reported to be quite limited.

In conclusion, most teachers do not make use of the potential of ICT to contribute to the power of learning environments. Thus, computers are used mainly to complement rather than change existing pedagogical practice. Teachers who applied powerful learning environments in their classes, who valued ICT as a means to support pupils' active and autonomous learning, and who were more confident about their skills in using ICT, were more likely to use open-ended types of ICT in their teaching practice. Male teachers appeared to favour open-ended use of ICT more than female teachers did. In addition, open-ended use of ICT, which is expected to contribute to the power of learning environments, was more likely to occur when a larger number of computers were available. The power of the learning environment and the availability of a sufficient number of computers contributed most to the probability of the use of open-ended ICT applications.

In order to further optimize learning environments in primary education, teachers should be made aware of the potential of ICT to contribute to the power of learning environments and to stimulate pupils' active and autonomous learning. Moreover, teachers' skills with regard to the use of ICT as a means to support powerful learning environments should be fostered. In this respect, issues on the use of ICT in curriculum differentiation and the organization of ICT to support co-operative group work are of particular importance.

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