# The value of pair programming in the IT classroom[1,2]

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## ABSTRACT

*In the South African curriculum, Information Technology (IT) is one of the elective subjects in high school. In IT, 60% of the subject focuses on software development, an aspect that has proved to be challenging. In this article, we present a case for implementation of pair programming in the IT class. IT learners and teachers (from the North West and Eastern Cape Provinces in South Africa) were asked to implement pair programming in their classes, and to report on their experiences afterwards. From the results, it became evident that both IT teachers and learners appreciated the use of pair programming, as it improved their critical thinking skills, fostered social skills and assisted in their acquisition of programming skills. In a society where IT learners are required to keep up to date with changes in the field, pair programming holds great advantages to share resources and acquire a variety of skills.*

**Keywords:** pair programming, Information Technology education, teaching-learning strategies, cooperative learning

## INTRODUCTION

In South Africa, Information Technology (IT) learners are learners who have elected IT as a subject in their Grade 10 year (or later) (Department of Basic Education [DoBE], 2012). The subject is divided into five core areas of which solution development makes up 60% of the curriculum (DoBE, 2012). Solution development in the case of this subject includes algorithms, web development, introduction to solution development, application development and software engineering principles (DoBE, 2012). The South African curriculum for IT also includes four other core areas: communications technologies, systems technologies, internet technologies, data and information management, and social implications – none of which make up more than 10% of the curriculum. For learners not to be adequately equipped with the necessary skills to be successful in these five core areas, but especially in solution development (programming), is a great disadvantage. In an era where there are more changes in technology than ever before and where we are constantly aiming to empower learners to keep up with these changes themselves (Guglielmino, 2013), it is of vital importance to create self-directed learners. One aspect of self-directed learning (SDL) that

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coincides strongly with computer programming is critical thinking. If learners have the ability to be critical thinkers they will also be able to discern between right and wrong information, good or bad written code, and appropriate and inappropriate practices.

Critical thinking has been regarded as one of the most important life skills needed to be successful in life, and subsequently it has gained great emphasis in educational discourses (Hyslop-Margison, 2003). Critical thinking is associated with all levels of education (Tiwari, Lai, So & Yuen, 2006) and is a prime objective of education worldwide (Fahy, 2005) in order to assist learners with becoming lifelong learners (Paul & Elder, 2005). If we refer to the wider context, the TIMSS report indicates that learners in general in South Africa compare unfavourably with learners in other countries in terms of Mathematics (a subject field influenced largely by critical thinking skills) (TIMSS & PIRLS, 2011). Critical thinking also plays a role in the success of IT as a school subject.

In South Africa, a new curriculum has been implemented (DoBE, 2012). The IT field and the programming language has changed from a procedural to object-oriented programming language: with Grade 10 IT learners starting with a visual programming language (like Scratch) before moving onto an object-oriented programming language (like Delphi). Researchers such as Klimovienė, Urboneine and Barzdziukiene (2006) emphasise that the correct implementation of cooperative learning (CL) could increase critical thinking skills. We, therefore, report on the implementation and value of pair programming as a cooperative learning strategy in the Grade 10 IT classroom.

In this article, pair programming and the IT class is theoretically underpinned, followed by a discussion on scholarly work previously done in this regard. The research process followed to investigate pair programming in this context is discussed, ending with the data gathering methods and instruments used. Finally, the results are discussed ending with concluding remarks and the limitations of the research.

## BRIEF THEORETICAL BACKGROUND

The theoretical framework upon which this research is based is a combination of the socio-cognitive and the constructivist learning theory. The socio-cognitive learning theory implies that individuals bring their own set of mental models, cognitive dispositions and life experiences while interacting within a social environment (Ringberg & Reihlen, 2008). Learning is therefore seen as a social and collaborative activity (James, 2006). Within the constructivist theory, individuals construct their own knowledge (Vygotsky, 1978). When combining these two theories of learning, it is evident that prior knowledge and experience are important aspects when working together actively in constructing new knowledge (in terms of understanding and problem solving) in the social environment. In South African schools, learners' backgrounds and experience levels regarding computer access differ vastly as inferred from the community survey results that only 24.5% of households had access to a computer in 2016 (Statistics South Africa, 2016). By having the opportunity to engage in cooperative endeavours, learners could share knowledge and amalgamate their own lived experiences with this new-found knowledge within a social environment. For learning to occur effectively, learners need to take responsibility for their own learning (albeit in a social environment) and therefore be self-directed in their learning. The aim of this research is to investigate whether the use of pair programming in the IT class (emphasising the social aspect) could equip learners to cope with the challenges of computer programming (emphasising the cognitive aspect) and empower them to be critical thinkers, and to take responsibility for their own learning (emphasising SDL). The research question that guided this investigation was: To which extent, if any, pair programming supports critical thinking and SDL in the IT classroom?

## CONCEPTUAL FRAMEWORK

Pair programming has its origins in the computer software industry; however, it has been emphasised as having educational advantages by several educationalists from various fields (Mentz, Van der Walt &

Goosen, 2008; Williams & Kessler, 2002). Pair programming involves having two individuals working on the same task at one computer – one individual fulfilling the role of the driver (working with the mouse, keyboard, pen, etc.) and the other individual fulfilling the role of the navigator (gathering resources and asking critical questions to help guide the driver) (Williams & Kessler, 2002).

Pair programming has not only been proved successful in the South African context but in a global context too. Williams and Kessler (2002) state that through pair programming, computer programmers have the opportunity to engage in several skills that increase their likelihood of reaching success in programming endeavours. Although originally viewed from a collaborative learning stance, pair programming has been positioned in CL by Mentz et al. (2008). They (2008) emphasise the incorporation of the five basic elements of CL into pair programming, namely: positive interdependence, individual accountability, social skills, face-to-face promotive interaction, and group processing, all of which contribute to the success of pair programming. Mentz et al. (2008) found that the move to CL as a basis for pair programming improved the likelihood of success in their classes. Pair programming with a CL basis has been used in other studies in the South African context. Hahn (2010) investigated assessment during pair programming in a second-year pre-service teaching class. Breed (2010) focused specifically on metacognition during pair programming and implemented pair programming in Grade 10 IT classes – also noting success with pair programming. Liebenberg (2010) found that pair programming in Grade 10 IT classes significantly increases learners' enjoyment of the subject. Although these studies emphasised the success of pair programming, pair programming is still not commonly used in South African IT classes.

In pair programming, IT learners have the opportunity to engage in several social and academic endeavours (Williams & Kessler, 2002). Engaging and promoting critical thinking through questioning during pair programming is also probable. Critical thinking is most widely defined as a 'purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation, and inference, as well as the explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgement is based' (Facione, 1990: 2). From the definition of critical thinking, already it is evident that the socio-cognitive/constructivist theory is prevalent, as critical thinking in itself includes both the cognitive aspects (interpretation, analysis, evaluation and inference) as well as the possibility that the social aspects can play a role in the cognitive process (evidential, conceptual, methodological, criteriological, or contextual considerations). Critical thinking as defined here also makes mention of the self-regulatory aspect, underpinned by SDL.

SDL is defined by Knowles (1975) as a five-step process where an individual takes initiative in:

- diagnosing learning needs
- formulating learning needs
- identifying human material resources for learning
- choosing and implementing appropriate learning strategies
- evaluating learning outcomes.

These five steps are not only evident in critical thinking, but can possibly also be achieved through pair programming if implemented appropriately.

## RESEARCH PARADIGM AND DESIGN

In this section, the research paradigm that informed the research process as well as the research design is discussed. The discussion on the research design includes the research process and methodology implemented in this investigation.

*Research Paradigm*

Creswell (2009) describes pragmatism as a paradigm concerned with establishing what works. The pragmatist researcher therefore focuses on the research problem rather than on the research process. Creswell (2009) continues by noting that pragmatism is not committed to any specific research methods (accommodating the mixed methods research), but gives researchers the freedom to choose what they feel would work as the truth is seen as 'what works at the time'. In order to answer the research question the pragmatist research paradigm informed this research.

*Research Design*

A mixed method (QUAN-qual sequential) research design was used. The quantitative investigation made use of a causal study design (Singh, 2007), as an intervention (pair programming) was implemented in an attempt to verify the effect of the intervention on the set variables (critical thinking and SDL). The qualitative investigation made use of an interpretivist research design, as it set out to understand learners' and teachers' views of the proposed pair programming intervention.

*Sampling*

At the time of the research, seven out of the nine provinces in South Africa implemented Delphi as a prescribed programming language and two provinces implemented Java. From the provinces that implemented Delphi, the two provinces selected were purposefully selected based on a similar number of schools hosting IT at Grade 10 level. These two provinces were the North West Province and Eastern Cape Province (it should be clear that the purpose of selecting these provinces were not to compare them, but rather to get a broader representation, within a limited budget, of IT classes in South Africa). In order to decrease bias, five schools (out of a possible 20) from each of these two provinces were randomly selected (from rural and urban backgrounds) to implement pair programming. All these schools were asked whether they would be willing to participate in the research and implement the proposed strategy (pair programming). In the North West Province, three schools opted to participate and two schools from the Eastern Cape chose to participate. In total five schools (five Grade 10 IT teachers and 71 Grade 10 IT learners) participated in the research.

*Research Method – Measuring Instruments, Data Collection and Analysis*

To measure the effectiveness of pair programming in Grade 10 IT learners (quantitative investigation), the Cornell Critical Thinking Test – Level X and the Cheng, Kuo, Lin and Hsieh (2010) SDL instrument were used. Both instruments had been used in high schools previously and proved reliable within other contexts (Lombard & Grosser, 2008). These two questionnaires were used to conduct a pre-test and after six weeks of pair programming, the same questionnaires were completed as post-tests. Additionally, a qualitative section consisting of two open-ended questions on critical thinking and pair programming was added to the post-tests (in the form of a paper-based narrative) to explain any changes in the learners' critical thinking and SDL skills further. The questions asked learners to comment, firstly, on whether they felt that their IT class had developed their critical thinking (in line with a given definition of critical thinking) and secondly, how they experienced the pair programming in their IT class. One of the researchers conducted the pre-tests and post-tests with the IT learners in order to have questionnaires completed in a controlled setting.

IT teachers participated in two semi-structured interviews: one before the intervention and one after the intervention. A semi-structured interview schedule was used to guide the interviews in both provinces and all teachers involved in the study were interviewed by the same researcher.

The Statistical Consultation Services of the North-West University (NWU), Potchefstroom Campus analysed the data using Hierarchical Linear Models (Garson, 2012). The qualitative data gathered from teachers

and learners were transcribed verbatim. Once transcripts had been double-checked, they were analysed by making use of emerging codes, which in turn were put into categories, which then formed themes. In a later section, the results from learners and teachers are discussed.

Ethical clearance for the research was obtained from NWU. Permission to conduct research in the provinces was obtained from the departments of education in the respective provinces. Furthermore, permission from the heads of schools as well as the IT teachers was obtained. As learners were all minors, informed consent forms were signed by parents in order to have learners participate in the research.

*Intervention*

IT teachers participating in this research were not familiar with pair programming at the onset of the research. All teachers in the research received a once-off face-to-face individual professional development session after school hours (presented by one of the researchers). During this session the researcher engaged in an informal discussion with the teachers regarding pair programming and how it could be implemented in the IT classroom. Teachers were also given a manual explaining the theory of pair programming and providing practical examples as to how pair programming can be implemented. Apart from the manual, teachers received key rings with characteristics of good pair programming printed on it (to hand out to their learners) as well as an animation video (explaining pair programming) to be shown to learners. Once the professional development session had been conducted, teachers were asked to implement pair programming in their Grade 10 IT classes for approximately six weeks (the longest possible timeframe between two school holidays). Although the researchers had no control over the assignments and activities used in the class, all teachers were asked to implement pair programming in the same way (as discussed in the conceptual framework of this article). No classroom observations were done, and therefore teachers had to be trusted to implement the strategies correctly.

## RESULTS

*Learners' Questionnaire Results*

Before results are discussed, Table 1, illustrates the biographical background of the IT learners.

*Table 1:*
*Biographical Information of IT Learners in this Research*

| Biographical item | Options | Frequency (f) |
|---|---|---|
| **Age** | 15 years | 28 |
| | 16 years | 28 |
| | 17 years | 5 |
| | 18 years | 6 |
| | Older than 18 | 3 |
| | Total | 70 |
| | Non response | 1 |
| | Grand total | 71 |

| Biographical item | Options | Frequency (f) |
|---|---|---|
| **Gender** | Male | 44 |
| | Female | 27 |
| | Total | 71 |
| **Home language** | Afrikaans | 18 |
| | English | 28 |
| | isiNdebele | 0 |
| | isiXhosa | 5 |
| | isiZulu | 0 |
| | Sesotho sa Leboa | 0 |
| | Sesotho | 2 |
| | Setswana | 16 |
| | siSwati | 0 |
| | Tshivenda | 0 |
| | Xitsonga | 0 |
| | Other | 1 |
| | Total | 70 |
| | Non response | 1 |
| | Grand total | 71 |
| **Rural/Urban** | Rural | 17 |
| | Urban | 54 |
| | Total | 71 |
| **Province** | North West | 42 |
| | Eastern Cape | 29 |
| | Total | 71 |

The IT learners in this research all ranged between the ages of 15 and 18 years of age (the majority being 15/16 years old). The most prevalent home language was English. As expected, few female students (only a third of the sample) and few learners from rural areas were represented although the sample was drawn randomly from the two provinces.

In order to establish whether there had been any significant increase/decrease in the Grade 10 IT learners' critical thinking skills after the implementation of pair programming, the effect sizes as calculated by comparing the pre- and post-tests are reported in Table 2.

*Table 2:*
*IT Learners' Total Critical Thinking Scores*

| | School code | N | Pre/Post | Mean | SD | p | d |
|---|---|---|---|---|---|---|---|
| Total for critical thinking | 1 | 4 | Pre | 17.3750 | 14.30253 | 0.043 | ***0.87 |
| | | | Post | 29.7500 | 8.87412 | | |
| | 2 | 17 | Pre | 0.9412 | 5.32354 | 0.035 | ***0.81 |
| | | | Post | 5.2647 | 10.16292 | | |
| | 3 | 10 | Pre | 32.9000 | 12.10785 | 0.284 | *0.21 |
| | | | Post | 35.4500 | 13.43596 | | |
| | 4 | 19 | Pre | 28.0526 | 12.11621 | 0.131 | *0.29 |
| | | | Post | 31.6053 | 10.42643 | | |
| | 5 | 21 | Pre | 30.0714 | 12.25182 | 0.019 | *0.33 |
| | | | Post | 34.1429 | 9.91103 | | |

* small effect
** medium effect
*** large effect

From Table 2, it is evident that the critical thinking skills of the IT learners in all the schools increased after the pair programming intervention. For two schools (school 1 and school 2), there was a large practical significant difference between the pre-test and the post-test, and for the other three schools (school 3, school 4 and school 5), only a small practical significant difference was reported. Possible reasons for these differences between schools are elaborated on in the discussion section. In Table 2, it is also evident that the critical thinking scores of schools differed vastly. The critical thinking total score had a maximum value of 71; thus, it was also clear that learners performed relatively low in critical thinking as measured by this instrument. School 2's learners scored the lowest in their initial critical thinking test illustrating that critical thinking was not really evident in these learners.

In Table 3, each school's mean score for SDL (from a maximum score of 100 for each learner) for the pre-test and post-test as well as the statistical and practical significance between the pre- and the post-test are reported.

*Table 3:*
*IT Learners' Total SDL Scores*

| | School code | N | Pre/Post | Mean | SD | p | d |
|---|---|---|---|---|---|---|---|
| Total for self-directed learning | 1 | 4 | Pre | 80.4000 | 9.85089 | 0.413 | *0.26 |
| | | | Post | 83.0000 | 11.48913 | | |
| | 2 | 17 | Pre | 80.4118 | 9.06958 | 0.792 | 0.05 |
| | | | Post | 80.8588 | 8.21455 | | |
| | 3 | 10 | Pre | 74.9800 | 9.71388 | 0.066 | 0.17 |
| | | | Post | 76.6000 | 10.18932 | | |
| | 4 | 19 | Pre | 70.7193 | 7.96153 | 0.238 | *0.34 |
| | | | Post | 73.4140 | 10.57660 | | |
| | 5 | 21 | Pre | 82.0190 | 8.24667 | 0.942 | 0.01 |
| | | | Post | 81.9238 | 8.89617 | | |

* small effect
** medium effect
*** large effect

From Table 3, it is evident that in the majority of schools, IT learners' SDL increased after the pair programming intervention. For two schools, there was a small practical significant difference between the pre-test and the post-test, and for the other three schools, no practical significant difference was reported. In School 5 there was a slight decrease but not significant. Clarification as to why this is the case is given in the discussion section. IT learners' SDL did not differ greatly between schools, as is evident from Table 3.

*Learners' Narrative and Teachers' Interviews Results*

In learners' narratives, they were given a definition of a critical thinker and asked firstly, to say whether and how the IT class had developed them as critical thinkers and secondly, to describe their experiences of pair programming in the IT class. IT teachers were asked an open-ended question on how they experienced pair programming in their IT classes. From learners' narratives and teachers' interviews, aspects relating to critical thinking and SDL were extrapolated. The following codes, categories and themes emerged from the narratives of the learners and the interviews of the teachers (in the discussion later, codes are indicated in bold).

*Table 4:*
*Codes, Categories and Themes identified from IT Learners' Narratives and IT Teachers' Interviews*

| IT learners' codes | IT teachers' codes | Categories | Themes |
|---|---|---|---|
| Problem solving | Problem solving | IT focuses on problem solving | Critical Thinking aspects |
| Analysis | | IT class encourages cognition/metacognition | |
| Decision-making | | | |
| Evaluation | | | |
| Logic | | | |
| Planning | | | |
| Reasoning | Reasoning | | |
| Thinking | Thinking | | |
| Creativity | | IT class encourages positive dispositions | |
| Inquisitiveness | | | |
| Questioning | Questioning | | |
| Use of different perspectives | Use of different perspectives | Use of different perspectives | |
| Confidence | Confidence | IT increases sense of self | Self-Directed Learning aspects |
| Introspection | Responsibility | | |
| Open-mindedness | | | |
| Academic achievement | Academic achievement | IT class creates platform for cognition/ metacognition | |
| Understanding | | | |
| Knowledge of the field | Knowledge of the field | IT addresses knowledge of field and application thereof | |
| Life skills | Active learning | | |
| | Use of resources | | |
| Sharing of knowledge | Sharing of knowledge | IT class stimulates learning agility | |
| Independent learning | Independent learning | | |
| Learning with the help of others | Learning with the help of others | | |
| Life skills | | IT class promotes life skills | |
| Communication | Communication | | |
| Listening skills | | | |
| Respect | | | |
| Social skills | Social skills | | |

From Table 4, it is evident that two major themes were identified: Critical Thinking aspects and Self-Directed Learning aspects.

*Critical Thinking Aspects*

Learners and teachers mentioned several aspects that can be themed under critical thinking, which will be discussed next.

*Information Technology class focuses on problem solving*

IT learners in this research commented on the fact that the IT class had improved their **problem-solving** skills.

> We are always finding solutions for problems that don't even exist yet' (Learner from School 3).

Furthermore, one learner clearly stated that they saw pair programming as a tool for developing problem solving skills:

> I enjoy pair programming as it is a combination of brain that work together to solve a problem. It helps to learn and understand the work better (Learner from School 4).

Half of the teachers noted that problem solving had been addressed while the learners were doing pair programming and that the learners solved some problems with much less effort when working in pairs than when working alone.

*Information Technology class encourages cognition/metacognition*

Several cognitive and metacognitive abilities were identified from IT learners' narratives and teachers' interviews. IT learners did however illustrate more of these abilities than their teachers did. Cognitive abilities such as **decision-making**, **logic**, **reasoning** and **thinking** were all identified from the majority of IT learners' narratives, whereas only thinking and reasoning were identified from teachers' interviews. IT teachers did not illustrate any use of metacognitive abilities in their IT learners, whereas the IT learners mentioned that **planning** was important, that they **evaluated** their solutions and analysed the problems constantly (all of which are metacognitive abilities), for instance:

> This challenged me to think more about something before I act or program (Learner from School 5).

*Information Technology class encourages positive dispositions*

Positive dispositions to promote critical thinking were also identified from both IT learners and teachers. The disposition that was most evident was that of **questioning**. One IT teacher and several IT learners emphasised how the IT class had encouraged them to practise questioning, not only in the IT class, but also in everyday situations, e.g.

> I'm able to ask questions if I don't understand the teacher (Learner from School 2).

And

> The channel was open for all of them to ask any question and give answers, so I think they're feeling that they are so free to say anything' (Teacher from School 2).

A number of IT learners also commented on the fact that they felt the class made them more **creative** and that they were more **inquisitive** after pair programming than before pair programming.

*Information Technology class illustrates use of different perspectives*

By implementing pair programming and allowing learners to experience other learners' opinions, IT learners in this class had the opportunity to **use different perspectives**. The majority of learners and teachers commented on the fact that learners acquired different perspectives:

> … the other group definitely learned some other ways of thinking (Teacher from School 3).

> I learnt to solve a problem in more than one way (Learner from School 1).

> I have learnt not to just think in one way but have tried to develop different ways of thinking to have an idea of how the other people's brains works (Learner from School 3).

It was evident in this research that, although no deliberate critical thinking instruction was implemented, critical thinking development still occurred. Apart from the critical thinking theme emerging from the data, an SDL theme also emerged and will subsequently be discussed.

*Self-Directed Learning Aspects*

From teachers' interviews and learners' narratives, the following SDL aspects were identified.

*Information Technology class increases sense of self*

IT learners commented on how their confidence had increased, e.g.

> It also helped me to improve my self-esteem when I am communicating with other[s] (Learner from School 2).

Learners also illustrated that **introspection** and becoming more **open-minded** were evident in the IT classes. The majority of IT teachers also noted that their learners' confidence had increased. Furthermore, one IT teacher also noted that the learners in her class had learnt to take more **responsibility** for their work as they were held accountable for each other's work.

*Information Technology class creates platform for cognition/metacognition*

Cognitive and metacognitive abilities were evident from IT teachers and learners. A shared cognitive aspect was **academic achievement**, where both IT teachers and learners noted that learners more easily grasped concepts and therefore had a greater likelihood to achieve academically after the implementation of pair programming, e.g.

> I could see when they were doing the tests, the ones that used to be clueless in the first and second term knew more now (Teacher from School 4).

IT learners also commented on the fact that their **understanding** in the subject had increased greatly as a result of the pair programming.

*Information Technology class addresses knowledge of the field and application thereof*

Although learners would have gained **knowledge of the field** of computers and software development in any case, it was evident (from what learners and teachers reported) that learners' knowledge of the field had increased due to the implementation of pair programming, e.g.

> I can see that they code much better and what they write makes more sense (Teacher from School 4).

Furthermore, teachers also noted that learners were more actively involved (**active learning**) in the learning process, which gave learners an opportunity to apply the knowledge they had acquired.

*Information Technology class stimulates learning agility*

SDL requires learning agility. Although teachers in this research stated that learners had the opportunity to learn to work together and to gain knowledge and experience from their peers, it was also evident that

learners still acquired the skills to work independently **(independent learning)**, e.g. 'there's help where I need help to and also to do things or programs on my own'.

*Information Technology class promotes life skills*

Learners from the IT classes noted that the class had developed their **life skills** as well as **social skills**. Social skills that were specifically identified were **listening skills**, **respect** and **communication skills**. IT teachers had a similar notion where they emphasised aspects like **social skills** and **communication**. These skills can largely be attributed to the fact that

> this [pair programming] is better than being alone because communication and questions are helpful resources (Learner from School 4).

## DISCUSSION

In this research, we found that CL in the form of pair programming underpinned by the socio-cognitive theory can increase not only critical thinking in IT learners, but there is also evidence that it could improve their SDL.

IT learners in all schools in this research showed an increase in critical thinking. It is therefore possible to deduce that, in accordance with Klimovienė, Urboneine and Barzdziukiene (2006), CL (in this research, pair programming) increases critical thinking. When referring to the quantitative data, learners' mean scores for critical thinking increased after the pair programming intervention. When looking at the analyses of the qualitative data, categories pointing to critical thinking development were evident.

The learners see pair programming as a tool for problem solving which made them more creative and inquisitive - emphasising only some of the advantages of pair programming in accordance with Williams and Kessler (2002). Working together as a team also provided them with new perspectives as working together allows them to solve problems in more than one way. According to the learners, pair programming increases their questioning abilities. They can not only immediately rely on the support of their partner when they do not understand, but also engage in critical questioning, in-depth discussions and reasoning to solve a specific problem together. Teachers confirmed the advantages of pair programming for critical thinking development by noting that learners' thinking and reasoning had been stimulated through pair programming. Interestingly, thinking and reasoning were also emerging categories from the learners' data. It is thus clear that pair programming gives learners the opportunity to engage actively in problem solving through reasoning, questioning and reflection which improves their critical thinking development.

Although not as prominent as the critical thinking development, IT learners' mean scores for SDL also increased after the intervention (with the exception of one school). As evident from a teacher's interview, learners in her class had learnt to take more responsibility for their own work as well as their peer's work after the implementation of pair programming. Positive interdependence and individual accountability - two of the key elements of cooperative learning that need to be addressed during pair programming (Mentz et al., 2008) - may have resulted in this increase in the learners' sense of responsibility; these elements emphasise that each learner needs to take responsibility for their contribution and the success of the group. SDL is a necessity and any indication of an increase in self-directedness is positive.

This research has shown that implementing pair programming with the CL elements influenced learners' development of critical thinking and SDL development. The researchers were not able to implement pair programming in the classes themselves and therefore some variability in the way teachers implemented it in their classes may have been possible as evident from their responses in the interviews. Regardless of this

variability, implementing pair programming proved advantageous when aiming to develop IT learners' critical thinking or SDL.

## CONCLUSION

In this research, it was evident from the body of scholarship that IT learners need critical thinking and SDL in order to increase their likelihood of succeeding in this subject, which is constantly changing and requires problem solving, abstract thinking and creativity. This research shows that IT teachers and learners realised the value of pair programming for SDL development and especially for critical thinking development; however statistically based, an overall increase was not evident in SDL development. It is recommended that IT teachers implement pair programming more frequently as it not only serves to develop IT learners' critical thinking but also equips them with the necessary skills to cope with the challenges the subject poses.

The research comprised a small sample, which limited the generalisation of the results; however, generalisation was not the aim, as we attempted to set the stage for future studies. This research indicated positive evidence of increased critical thinking and self-directedness among learners after the implementation of pair programming, which could also hold advantages for the implementation of CL in other school subjects. In any school subject where learners need to solve authentic problems, CL will give learners an opportunity to reason, question and reflect together, which may increase their critical thinking and SDL. It is recommended that further research on the implementation of CL on a larger scale, including other school subjects, should be conducted in the future.

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