Zone of Proximal Development in the Era of Connected Computers


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The zone of proximal development (ZPD) could be a fruitful framework for understanding processes that enable learning in a collaborative environment. How can one create a platform with connected computers which would allow the learners to create a ZPD by design? We discuss design requirements for such a platform and we present two examples to substantiate our arguments. The examples considered are learning of arithmetic and learning to type using a Indic keyboard. We found that the natural desire of the learners to share and gain knowledge with peers could become an inherent source of sustainable interactions which facilitate learning. The learner's role shifts dynamically between being a mentor and a mentee. The digitized interactions offer the platform as a 'player' for both synchronous and asynchronous modes of accessing the otherwise fluid social interactions. This facilitates the creation of a motivating context for engagement (both online and offline), which is nothing but a ZPD, that is essential for learning.

Introduction

The concept of zone of proximal development (ZPD) as developed by Vygotsky relates to the tasks that can and cannot be done by a child with the help of more able peers (Vygotsky, 1978). The ZPD allows us to look at the potential aspects of learning that can be brought out with a slight nudge to the learner. These nudges essentially are in the form of social intercourse with peers, who might know more than the learner about a given task. Vygotsky's original studies were conducted in environments in which the zone was elaborately constructed to enable this transfer of knowledge. In this study we explore a digital workspace which by design facilitates learning by creating a ZPD.

We provide two case studies, both based on sharing the work in a collaborative computer-mediated environment in a classroom setting under contrasting conditions. The two examples exemplify the role of connected computers in bringing meaningful and intrinsically motivating collaborative interactions towards a learning objective. Case study methodology was used in this study. In the first case study, involving an arithmetic game we have a pre and post test involving arithmetic proficiency. The data collected also included audio recordings, observer notes and logs from the computers. In the second case study, involving Indic typing the data collected includes observer notes, video recordings and logs from the computers.

The theoretical framework derives from the concepts of ZPD (Vygotsky, 1978), scaffolding (Bruner, 2009) and CSCL (Stahl, 2006). Vygotsky (1978) defines ZPD as: *"The distance between the actual* *developmental level as determined by independent problem-solving and the level of potential problem solving as determined through problem-solving under adult guidance or in collaboration with more able peers."*. Bruner (1985) introduced the term, scaffolding, as a metaphor of support a tutor provides to a learner till successful completion of a learning task. Scaffolding *"is help which will enable learners to accomplish a task which they would not have been quite able to manage on their own, and it is help which is intended to bring learners closer to a state of competence which will enable them eventually to complete such a task on their own."* (Maybin et al, 1992).

In this conception the focus is on the individual learner and usually the more able peer is the teacher or the mentor and hence is *asymmetrical*. Symmetry in this process would mean that both the peers are at the same learning level. Asymmetrical here implies the more able peer is at least one level above the learner and not at the same level. Newman et al (1989) suggest that ZPD should be expanded beyond individual and asymmetrical focus. They argue that even groups of learners can be considered as units of analysis and learning can happen symmetrically. In this case the symmetric would mean that the interacting peers are at the same level of conceptual development. Fernández et al (2001) suggest that idea of scaffolding can be used to understand how groups of learners can use language to support shared thinking and learning. Maybin et al (1992) suggest that learners in a group can understand concepts and complete tasks using linguistic 'scaffolding tools'. These tools include questions, feedback and explanations of the structure of the task. We have used their framework to analyse the tasks in our study.

How do the ideas of ZPD and scaffolding change on introduction of connected computers for interaction and also for setting of the learning tasks? Studies in the field of Computer Supported Collaborative Learning (CSCL) look into this angle (Stahl, 2006; Stahl et al, 2006). In CSCL context, group cognition exists at three levels, individual level (talking to ourselves), small group level (group discourses) and community level (adapting to community way of thinking, doing and interacting with the community). The focus, in this approach, is the actions of a small group mediating between the two levels (individual and community) (Stahl, 2006). In the first case study involving the arithmetic game, community level is absent while in the second case study of Indic typing all three levels are present.

Study 1: Learning arithmetic in a collaborative environment

The first study was done with primary school children of a semi-government school. An instant messaging game was designed and developed to help students learn arithmetic skills (addition, subtraction and multiplication). The study was done with 24 students of grade 4 age ranging from 9 to 11 years. Each student worked on a XO (laptop) for 45 mins every alternate day. They were connected with each other through WiFi. Students' proficiency in arithmetic was measured before and after the intervention and computer logs were collected throughout the intervention. Students and teachers were interviewed at the end of the intervention. The data analysis showed that the intervention leads to a significant improvement in students' proficiency in arithmetic (Shaikh et al, 2017). Students developed better strategies to solve arithmetic problems and those strategies diffused rapidly in the classroom.

The learning game proceeds as follows: Any one student starts and announces arithmetic game letting other interested students join. Nature of the game is similar to guidelines given by Kirriemuir & McFarlane (2004), though we did not know about these guidelines when the game was designed. For an addition game, the students decide a starting number and a stepping number. This decision happens through a verbal discussion in the class. The game starts once the starting and stepping numbers have been decided. The students keep on adding the starting and stepping number and type the results in the game interface. For example, if the starting number is 7 and stepping number is 3, a typical entry by a student would be: 7, 10 (7+3), 13(10+3), 16(13+3) and so on. The aim of the game is to get to the first three digit number of the series. The game is paused when any participant announces winning or someone points out mistakes done by other players. In both the cases, all the participants examine all the posts of student in question and through consensus decide whether computations are correct or not. The game proceeds till every student has achieved the end goal of reaching a three digit number. A new game starts with a new set of starting and stepping numbers and the game continues.

The important design feature of the game is whenever any student posts anything on her laptop screen; it is immediately visible to all the other participants. Each student's posting has a specific color, which helps in differentiating and identifying different students. Starting number, stepping number and the last calculated number of the game are continuously displayed on the screen, which makes the calculations easy by providing accessible relevant information. When students post their answer, it stays in the history of the game accessible to the players or mentor for scrutiny, learning and feedback. Access to the history of students' actions is the new affordance of the digitized version of the game. If students want to win the game, they have to perform faster and accurate calculations. At the start of the game learners use the strategies known to them for calculating and posting. As the game progresses, when learners have access to the shared response from their peers, we see a change in their strategies. When a student senses from the postings that someone else is doing same arithmetic problem faster, she goes to that student and asks her about it. In general, the 'more able' peer is highly motivated to share their strategy. We have observed students using strategies described by Shrager & Siegler (1998): *Sum, Shortcut sum, Min, Count from first, Retrieval*. Apart from these known strategies we discovered another strategy during this task, use of *Multiplication Tables* to aid certain addition problems (in which the starting and adding numbers are the same) (Shaikh et al, 2013).

Study 2: Indic typing as collaborative puzzle solving

In the second study, we look at an introductory exercise in a digital literacy course for students of 9th class in government schools. This digital literacy course is part of a much larger project initiated to enhance school science, mathematics and English language learning using computers. The course had 16 sessions, of which each session lasts for about 90 minutes. We studied about 6 such classrooms in a rural area of Rajasthan state in India.

The current focus of the case study is the part where the learners are introduced to operating the computers and to the course platform where all interactions happen. The course platform is based on a server in the school and connects with the rest of the computers via a Local Area Network (LAN). The learners are given individual logins for the platform to create an internet like experience. The platform presents the course content to the learners in a structured manner like an online course. The platform features include writing a notebook entry, commenting on pages and notebook entries, uploading files and giving rating to comments and uploads, and adding relevant tags. These features enrich the interactions on the platform by motivating and incentivizing communication in multiple ways. Each user on the platform gets points for adding notebook entries, comments and file uploads. The users can see these points after each activity, thus allowing them to see their progress continuously during each session.

The students were allowed to talk to each other during the class and the teacher played the role of a facilitator to inform students about the task on a large TV display in the computer lab. At times the teacher helped the students with some technical details. Help material in the form of animated gifs were available on the platform. The learners also have access to a Student Handbook and large posters displaying the keyboard map. If we look at the three levels of learning (individual, group and community) for analysis as given by Stahl (2006), we find that learning happens at all three levels.

The digital literacy course is designed assuming that the learners have had no experience with the computers. The digital literacy course is presented in a bilingual mode and learners can respond to the typing tasks in either English or Indic languages. We have used the Inscript keyboard layout for typing of Indic scripts (Inscript Keyboard Layout, 2017). The Inscript layout provides a universal method of typing most Indian scripts. The Indic script in use there is Devanagari.

In our design we have tried to incorporate the expression of ideas of the learners as a context for typing. In this way, each learner and group had a unique text to type. Some of the contexts that we provided were writing about themselves (where are you from, what do you like, what are your hobbies etc.), writing stories from pictures, asking and answering questions based on a given text, etc. But the actual action of typing the words in the Indic script can itself be seen as an overarching puzzle-solving exercise. Overall, typing even simple words in Indic or English script can be challenging for beginners, as they have to ‘hunt’ for the required keys. For writing complex words in Indic scripts, particularly ones involving the combination of two or more letters, one needs to know the rules of combination. The learners are provided with a printed version of the Inscript keyboard layout which they can refer to while working. We present here a summary of our observations.

The learning to type in Indic scripts can be seen as a four step exercise, increasing in the degree of difficulty:

1. Finding the mapping of each letter (consonant and vowel) on the printout and also on the keyboard.
2. Pressing Shift + Key produces another letter.
3. Knowing that the modifiers of the letters always come after the letters.
4. Using the *halant* modifier (half-consonant) to combine any two letters.

Learners slowly discover these rules by either carefully studying the printouts and mapping them back on the actual keyboard or by trial and error. When groups of students get stuck with a certain combination they seek help from other groups or teachers. But just knowing how to type once is not sufficient, learners have to practice typing, otherwise they tend to forget what they have learned. The typing sessions were the first in the sequence, while the other sessions require this skill. As a result the practice of typing continues throughout the length of the course, which is about 16 sessions in all. Only by third or fourth session in the course, the first time learners can type full sentences with ease.

The design of the learning task invokes varied and sometimes unique challenges to the students. The fact that each group has a different content to type makes the setting rich for peer learning. A typical difficulty that one group is facing might be solved by another group. This creates a *dynamic* ZPD where the roles of the peer change between mentor and mentee. We call this ZPD dynamic as the roles of individual and groups change during the process of learning. There are no fixed roles, a ‘more able’ learner or group might seek help at a later point of time.

There are two modes of communication which we observed during the sessions. The first one was direct talking. This included asking for help from other members of the group, and from other groups in the class. Overall, it was observed that any new 'discoveries' made by any group, transmitted to others very fast. This typically happened by either, the discoverers' announcing it in the class *"This is how we made this word!"* or someone looking at the typed responses on the platform and asking *"How did you do this?"* by approaching that group. Approaching another group and looking at how they solved a problem (as evident by their post on the platform) was a common sight. There was an overall free flow in intra and inter-group settings. Most of the conversations that we observed in this case were of the exploratory kind (Fernández et al, 2001). This flow of ideas and knowledge was made possible by the platform, which allowed the learners to share and see the work of others. Without this sharing, it would be extremely difficult to elicit such responses from the students. Similar observations are made in our first case also.

Typically the learning task here demanded switching between and using multiple representations and modalities. Given a context, the ideas to make stories are formed in the minds of the individual learners. At the group level, there is an exchange of these ideas, verbally, and the final story is created after negotiations. The worksheet asked the groups to write their stories in their paper notebooks, which allowed externalisation of the stories from the minds of the learners, which makes it accessible to the group allowing for distributed cognition (Hollan et al, 2000; Hutchins, & Klausen, 1996). But there are several other reasons we ask the students to write their stories in their paper notebook. First is that it makes easier to type something that is ready. To type and think what to type at the same time is cognitively demanding for learners who are new to typing. The second reason is to provide a bridge between the text of physical paper notebook and the text on the computer screen. The computer content is not something special, but any content made by the students can be brought to the computer. This in a way demystifies the idea of a computer as an alienated device. This mediation of text from physical to digital is a good entry point to making the computer a device of their own. The third major reason is that writing is a highly involved cognitive task. According to Dix (2006), the first order of cognitive task is inner speech, second is public speech, and the third-order cognitive task is writing. In this framework writing is considered a third-order cognitive task. Writing things out helps us clarify many things and are different in kind than talking.

The text that they have written in the paper notebook challenges the students to find the keys to create the required words. This is mediation from notebook to paper printed keyboard map (having both Indic and Roman scripts) to actual keyboard (having only Roman keys) which happens via collaboration between the learners. In many groups we observed that one member looks at the printout, while other types the letters, and the third member tells what to type, this way the typing activity is like a *collaborative puzzle solving*. The final form of text is seen on the screen, where the learners can check the validity of their efforts immediately. The immediate feedback and chance to act on the feedback by editing their posts on the platform is helpful in consolidating the learning. In some cases we noticed that even the teachers gained new knowledge from the learners as the teachers underwent training to conduct these activities not too long ago and were not very conversant with computers or lacked practice.

The learners are encouraged to look at the posts made by their peers, where they can comment on the work of their peers. This provides another level of collaboration between the learners. They point out ways on how the text can be improved, mistakes in spellings fixed. This exercise creates a safe space for making mistakes which can be rectified. Learners also build negative expertise in avoiding common errors (for example, adding modifiers after the letters) in this exercise. A congratulatory word in the comments provides positive reinforcement for the learners. Thus we see that such an experience provides the learners with very rich experience of entry into computers where their own and peer knowledge forms the basis.

Discussion

We have looked in this article the possible ways of creating and curating a digital space for collaborative learning. The ideas of ZPD and scaffolding are played out in a digital space which allows the learners to make mistakes safely. In this context the role of the 'learned peer' is a *dynamic* one, with different learners playing the role at different times, as opposed to Vygotsky's (1978) asymmetric and Newman et al (1989) symmetric one. This allows for greater participation in the class from all groups and individuals. Also, such an environment presents a space for 'learned peers' to share their knowledge among others, such a space is usually absent in the traditional classroom. Though the context of the two studies we presented here uses different online platforms, the essential aspect in them is the *idea of sharing of the progress towards achieving a learning goal in a digital public space.* This makes the peer-feedback, self- and peer-learning possible. Such an approach provides essential scaffolding for the entire class to make mistakes and learn from them.

Instant sharing of the ongoing progress to achieve the goal plays an important role in this interaction. This sharing of work allows the formation of a ZPD by allowing learners to view and analyse faster strategies, and the dynamic interaction with peers helps the learners realize their potential. Posting on a computer screen also plays an important cognitive role, it frees valuable mental resources for doing tasks like mental calculations, deciding which strategy to use for given problem etc. (Hutchins, 1995). Same effect may not be possible when the game is played with pencil and paper, for example, it cannot be played by a large number of learners, work cannot be shared instantly with everyone, and the speed of response is very limited.

In both the studies, the externalisation of the problems, doing the sums online, and typing out their thoughts, helped the learners to visualise the process of learning. It is only by shared digital externalisation that such a process is possible. Concretisation of their own learning in the form of tangible and reproducible results helped the learners to accomplish the tasks by following the more competent peer or peer group when needed. This process inherently also allowed for self and peer-assessment, as the output of each individual and group were on public display and correctable by peers. Due to the digital nature of externalisation, correcting a mistake is much easier and doable. This externalisation acts as a scaffold when peers are symmetric in their level of conceptual development, in contrast to the Vygotskian model. This scaffold might be helpful immediately to certain peers, but due to 'permanent nature' (as compared to mere verbal help) it creates a lasting learning scaffolding which can be used later asynchronously by other peers. For example, a note or comment left by the peer can be read and be useful much later. One can think of such learning as being 'incidental', and it is only possible because of accessible externalisation. This can be seen as analogous to the various online help forums, where learners can get the required help by just browsing the older posts.

The self and peer assessment in this context also allowed multiple ways to correct possible mistakes by looking at peers and peer groups. For example, discovering multiplication strategy when using the same starting and stepping numbers. The public display also allowed others to actively point out potential mistakes and possible solutions for them, thus developing a "negative expertise" in the process (Minksy, 1994). For example, pointing out an incorrect combination of letters or spelling and telling a way to correct it. This cycle of feedback and subsequent corrections, is *emergent* and *dynamic* scaffolding which allows the learners to successfully complete the task. We call this scaffolding *emergent* as it evolves from interactions among the peers, where the roles of being a 'more able' peer are dynamically changing for different tasks.

Due to the nature of the tasks involved, it allowed the learners to accomplish the task in different ways. In the Indic typing study, for example, each of the individual and the group had a different thing to write. This created a variety of opportunities to learn from and also changed the problems that each group faced, for example, the need for a variety of combination of letters. The variety of the problems created new and challenging learning opportunities for the individuals as well as the groups. In case of the arithmetic study, different strategies were developed and discovered by individual students, which were discovered by peers. What we observed in both the studies is the urge to share the newly discovered strategies and solutions with the immediate group and the community. The rapid diffusion of strategies and solutions in the classroom was instrumental in making the collaborative learning possible. This diffusion was not pre-mediated by the mentors, but was emergent, natural, and spontaneous. In a regular classroom there are hardly any opportunities for such interactions to materialise, as there is monotonicity in the solutions to the tasks. In a regular classroom the avenues for collaboration are limited if there are any at all. Keeping these two points in mind while designing activities, it will provide richer engagements and learning opportunities to the students. We have seen these observations in two apparently different studies but similar in their design principles.

Further work is needed to see how the learners retain learning gained during these interventions. Another direction of investigation is to look at whether learners are able to transfer the learning to another task or domain. The preliminary observations from Indic typing study show that they could submit the remaining course assignments by typing in Indic languages. In case of arithmetic game, further study is needed to establish the transfer of knowledge to another problem solving contexts. In both our studies the levels of learning as indicated by individual, group and community were part of the same classroom. We would like to study how this scales when the community is no longer limited to the immediate classroom environment of the learner.

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