Peer-to-Peer Networks as Collaborative Learning Environments

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Abstract

The purpose of this paper is to study the use of peer-to-peer networks in combination with collaborative learning. The learning environments used in computer based education are normally client-server based solutions with some additional functionality developed for the collaboration needs. Peer-to-peer (p2p) technology is often suggested as a better solution because the architectures of peer-to-peer networks and collaborative learning are similar. The paper examines the most common problems with collaborative learning. It analyses the possibilities of the p2p environment and compares them with the needs in the collaborative process. The p2p environment offers interesting possibilities for communities but the functionality is not particularly well suited to small groups and collaborative learning. To make p2p an efficient tool for collaborative learning some additional functionality or combination with existing messaging and group software is needed.

KEYWORDS: peer-to-peer networks, computer based education, e-learning, collaborative learning, project oriented learning

1 Introduction

During the last decade web-based teaching has spread widely in engineering education. However, web-based teaching does not change the old teaching paradigm. It is still the teacher that provides the knowledge and shares it with the students. To activate the students and to prepare them for the challenges in working life, collaborative learning can be used [2]. The idea of collaborative learning is to change the teaching paradigm toward the point where the students, under the teacher's supervision, search the knowledge and share it with each other.

This principle of learning requires a lot of work from both teachers and students to be successful. It also requires good supervision and communication tools for the collaboration. Many server-based learning environments used in education support collaborative learning but the architecture of the system differs from the main principle of collaborative learning. The decentralized approach of peer-to-peer networks would better support collaboration.

Peer-to-peer (p2p) networks have so far mainly been used for sharing music, video and other large files between users. Recently also p2p-based Internet telephony has gained popularity. The technology offers efficient search engines combined with several sources for the same data which speeds up the data transfer compared to conventional client-server architecture. Large files can rapidly be downloaded to the user of p2p networks. This brings new possibilities in education if large audio or video files are used. The opportunity to use instant messaging with the user, that has the needed files, gives the students a natural way to collaborate. Many p2p environments allow users to browse the shared files directory on another peer and this enables further collaboration. The p2p environment normally used does not have any information structure or calendar tools as learning environments generally do have.

The goal of this paper is to examine whether the collaborative approach in learning can be applied by using p2p functionality. Research questions are:

- What are the essential requirements for successful collaborative learning?
- How can the p2p network be used and what benefits could it bring into learning?
- How should the teaching methods be changed to enable collaborative learning with p2p?
- Can the quality of the information produced be verified in any way and is there a risk of learning incorrect things?
- Is there a greater risk of so called 'free-riders'? A 'free-rider' is a peer or a person that consumes more resources than he offers.
- Do the p2p networks lack functionality needed for this form of education?
- How should p2p networks be developed to better support the collaborative learning process?

There is already some research work done in this area, though p2p applications are new. Some specialized educational p2p applications as COMTELLA [26], EDUCOSM [19], Edutella [22], Groove [10] and SpeakEasy [9] have been developed and the experiences of them have been reported. These have all been developed for some specific needs and they are still under development.

This paper considers in section 2 what the significant requirements for successful collaborative learning and especially project oriented learning are. Based on this, the benefits and drawbacks of using p2p networks to support the collaborative learning are analyzed in section 3. In section 4

a use case is presented and the experiences from it are summarized and in section 5 the conclusions regarding the combination of collaborative learning and p2p are drawn. Finally, some guidelines for future research and development are proposed.

2 Collaborative learning

By collaborative learning we generally mean that a group of students work together to discuss, argue, solve or evaluate something. A paradigm and taxonomy has recently been described by Cuseo [7]. According to Gokhale it is considered essential that the discussion topic is clearly stated and limited [11]. The task the group should focus on must also be clear to all the members. The task can be to write a report, produce a slide or only to make meeting notes about the opinions of the group. Important is also that everyone in the group participates in the discussion and brings opinions into it. To conduct such a discussion is not an easy task and there is a built-in resistance toward group work of this type in many communities.

2.1 Why use collaborative learning at all?

Learning by discussion and doing is much more efficient than learning by listening to lectures. The learning also reaches higher cognitive levels if you are forced to analyze, synthesize and evaluate in the process. According to Gokhale [11] processes where students of different knowledge and skills work together toward a commonly known goal by discussing and questioning each other are very effective. It has proved to develop both social and cognitive skills of the students.

Reasons for this can be found by studying Blooms taxonomy [3] for the cognitive domain (see figure 1). The level of understanding of a problem increases from knowledge to comprehension and further to application. From this stage analysis can be done and further synthesis and evaluation of the solution for a problem can be performed. The different stages in the taxonomy must be experienced before you can evaluate.

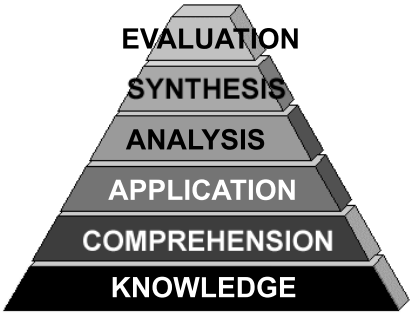

Figure 1: Blooms cognitive domain

According to research on average learning retention rates of students done by the National Training Laboratories, Bethel in Maine, [21] the highest retention rate of a student in education (90%) can be reached by 'teaching others'. The second highest retention rate (75%) can be achieved by 'practicing by doing' and the third highest rate (50%) by using 'discussion groups' in education. Combining these educational methods should at least in theory give a good learning result as long as the collaborative work contains the necessary components. That is exactly what we aim at in well organized collaborative learning.

2.2 Problems with collaborative learning

Not all group work is considered as collaboration and there are several tactical approaches used by students when group work is proposed. According to Waite et. al.[25] there are four obvious tactical approaches used by the students:

- Sequential segmentation, where every student works for a while and passes on the task to the next student.
- Parallel segmentation, where the students break up the task in subtasks that can be done in parallel.
- Natural selection, where everyone does the task separately but the best solution is selected as the group's answer.
- Collaboration, where the students interact closely during the performing of the task.

The first three approaches lead to results where everyone mainly works alone and thus the advantages of group work are reduced. These first three approaches are often selected by the students if they are allowed to freely choose how to work in the group. To avoid this, special measures must be introduced.

According to Leonardi[18] the reasons for using such tactical approaches in engineering education can be found in the student culture. Students generally avoid group work because of several different reasons. They might **prefer to work alone** and get the sole responsibility and full credit for the work as most of it is generally considered a product, not a process. They are aware of the obvious **risk of procrastination**, by themselves or others, which leaves no time for discussion and collaboration. Some students have a **need to experiment** by themselves to solve the problem instead of collecting the information to understand it first and then solve it. Students have a general **disregard for educational processes** and are focused on the end product, though the knowledge of the process may be essential for the task. Some students **consider themselves better** than the average student, just as every car driver normally does, partly as a result of working alone which has enabled the simplifying of complex phenomena. Some are **unwilling to support others** as they are not rewarded for that, but for the results and often their professors behave in that way themselves. Some students **lack the passion**, which should be the driving force for the subject and the task. A shared passion is needed for group work to succeed.

The starting conditions for natural collaborative learning are thus not encouraging. The collaboration must be well prepared and supervised to get the best results.

2.3 Critical components of collaborative learning

According to research of Noel LeJeune [17], who has done several research studies in computer science education, there are five critical components for collaborative learning:

1. The task given to the group must require the collective effort of each group member. This means that the individual knowledge of the students must be examined prior to group formation and the groups must be formed so that the skills of the students in a group are different.

2. The group size must be small enough to allow interaction between all the members. An optimal group size is 5 - 7 members according to LeJeune.

3. Competition within a group must be considered unwanted and all members must be discouraged to do so. If it is possible the examination should take into consideration this.

4. Each group member is personally responsible for the other group members contribution. Thus every group member's knowledge must be present and recognizable in the final report of the group.

5. Each group member is required to seek knowledge and skills from another members knowledge area and the assessment techniques must take that into consideration.

The teacher must assure and supervise that these criteria are fulfilled in all the groups during the performing of collaborative learning tasks.

2.4 Project oriented learning aspects

Collaborative learning is often combined with project oriented working to simulate the behavior of working groups in industry. This brings in the time domain and administrative aspects of a project in the collaboration and thus makes it more realistic. A project can be seen as an ad-hoc organization of experts to solve a specific task according to a given timetable. This is why the combination of the two educational methods mentioned is successful.

Melin and Cronholm [20] have studied the learning and examination of project oriented student work. They have found this method extremely efficient but they report the following four categories of problems: **Coordination problems** occur because of different desires about working times and geographical distance between project members. **Heterogeneity problems** occur because of different previous knowledge about topic, techniques of study and ways of thinking. **Motivation problems** occur because of differences in levels of ambition and commitment to task and goals. **Social problems** occur because of different personal chemistry and abilities.

The same problems also occur in real life working groups and can be considered quite normal. The collaborative learning develops the skills needed to overcome the problems if the group conflicts can be solved and non-creative group climate can be avoided.

3 Peer-to-peer environments

Collaborative learning differs from conventional teaching in the same way as peer-to-peer differs from the client-server approach. As the client-server approach resembles the student-teacher relationship in conventional teaching the peer-to-peer architecture resembles the roles of students in collaborative learning. This is probably why great educational expectations are put on peer-to-peer education. The peer-to-peer environment offers some tools for collaboration but do they really enable efficient collaborative learning? In this chapter the functionality and tools of the p2p environment is presented and then these are compared to the immediate needs of efficient collaborative learning. Can p2p offer solutions to the most common problems of collaborative learning described or does the p2p environment need new functionality? These are some of the questions we are trying to answer in this chapter.

3.1 Functionality of p2p environments

The p2p environments offer some basic functionality which makes them good for music and video sharing compared to the client-server approach. The basic functionality offered by most file-sharing p2p-software is:

- Efficient and easy to use search engines made especially for the p2p-networks. These are categorized for audio, video, image and application searches.

- File sharing of selected catalogs which sometimes includes the possibility to check which files a specific user shares.

- Down- and uploading of files, which includes checking of download and upload status for selected files.

- Library functions for the efficient categorizing of files.

- Player for the most common media files.

- Chat with users in general or joining of discussion rooms with specific topics.

- Instant messaging can usually be used only with a peer that downloads or uploads from the user.

Some p2p environments offer a function called grid computing or sharing of CPU cycles. This functionality is excluded here as there are few applications and the need for processing power is not the main interest in collaborative learning and education.

File-sharing peer-to-peer software usually lacks some essential functionality that could be useful for collaboration and project oriented learning such as:

- Email and instant messaging support with any user.

- Audio and video conversations and conferences.

- Sharing a whiteboard or application with others.

- Asking of remote assistance in problem situations which messenger software often have.

- Personal and group calendar functionality which is typical for team or group software.
- Newsgroups, Web logs or Blogs that enable open public discussion on a topic.
- Online user-editable database functionality (Wiki) for collaborative building of knowledge databases.
- Synchronization for off line work as the user reconnects to the network.

Some of these functions could easily be integrated in p2p software but as the main purpose of p2p has been file-sharing there is little need for these collaborative tools today and thus they have not been implemented. A growing use for p2p networks is in Internet telephony driven by Skype, that already announces 30 million registered users [23]. This shows that the audio and perhaps also the video conversation functions have a great need outside the pure educational purpose. Integrating Internet telephony in the existing file-sharing environments would definitely bring benefits to p2p. Part of the other functionality described has been integrated in special p2p learning environments as COMTELLA [26], EDUCOSM [19], Edutella [22], Groove [10] and SpeakEasy [9]. There is no open source software having the mentioned functionality available at the moment.

3.2 Collaborative learning and p2p

The experiences from the fully distributed COMTELLA [26] network are encouraging and show that the activity of the students have increased remarkably as the collaborative course 'Ethics in Information Technologies' was transferred from a web-site based environment to the COMTELLA p2p environment. The students' task was to search for relevant articles, summarize and rate them and to keep a personal public list of links to the articles the student has found and read so that anyone can find them (see figure 2). In this way the class together produces a high quality material for anyone interested. The most significant observations from the report are:

- The average number of contributions from the students increased from 4.63 to 11.52.
- The number of passive (noncontributing) students decreased from 56% to 17% of the class.
- The contributions of the top five students decreased from 78% to 39%.

These results show that for a certain task a p2p environment generally motivates and activates the students better than building a personal website for the purpose. The collaborative building of knowledge is more evenly distributed among the students and the top students do not have such a dominating role. As the students divide the research field, according to the parallel segmentation and natural selection tactical approaches mentioned, the given task is not fully collaborative but still representative. According to the report the student culture at the university seems to support collaborative learning better than engineering education generally does and thus the typical problems described do not disturb the collaboration.

In all computer based collaboration and especially in the p2p environment there is a great risk for 'free-riding'. According to Adar and Huberman [1] about 70% of the Gnutella users share no files at all though Svensson and Bannister [24] imply that the most important normative guideline for p2p networks is the rule 'Thou shalt share'.

The 'free-riding' is also a problem in educational use of p2p. Bretzke and Vassileva [4] propose that user interest, relationship and cooperativeness level should be used in order to eliminate free-riding in p2p networks. The user interest should be calculated, based on how frequently and how recently the user has made netsearches the interest area given. The user relationship calculation is based on the balance between downloading and uploading. This can for one user be calculated for the whole network or for a specific peer. The user cooperativeness level starts from a base level and moves toward selfish or altruistic depending on the actions. Selfish actions are typically: moving files to non-shared folders, terminating uploads and closing of the p2p-program. If the significance of the user cooperativeness level is clearly stated, it motivates the students to cooperate and thus stimulate collaboration.

Eikemeier and Lechner [10] approach another complexity in p2p systems and group collaboration. The benefits from large scale p2p systems as NAPSTER and GNUTELLA do not apply in small scale p2p environments. The scale effects that make file-sharing of music efficient in communities do not apply in small working groups of ten to twenty persons. Factors as reliability and quality of data are more important and version handling of project documents a necessity for a working group. Tools for project managing also play an important role. In small groups the trust in other group members links the group strongly together and helps in solving the task. This can not be observed in larger communities. Eikemeier and Lechner propose a division of p2p tools in team and community tools. According to their research p2p-based community-tools do not offer the functionality needed. Instead p2p-based group-tools as Groove [13] are recommended for distributed collaborative project work.

Edutella is an educational p2p network which is built on Sun Microsystems JXTA Framework. The JXTA Framework [12] provides a standardized architecture and the protocols needed to build an open source p2p network. Edutella is an open source p2p application for searching semantic web metadata. Edutella mainly consists of a library and a query language. The library can be used to form new Edutella networks that connect to the existing Edutella networks. The Edutella Query Language is suitable for querying semantic web metadata expressed in the standardized Resource Description Format. The goals and main services of the project are described in [22]. Edutella is an attempt to solve one of the major problems with p2p networks, namely the need of structurized metadata. In p2p networks the data is no longer organized as hypertext which easily can be navigated. Instead the information is scattered around on numerous peers and the metadata needed to find the files does not exist. This is generally not practical for educational purposes though it serves the needs of p2p well. Therefore, the first goal of the

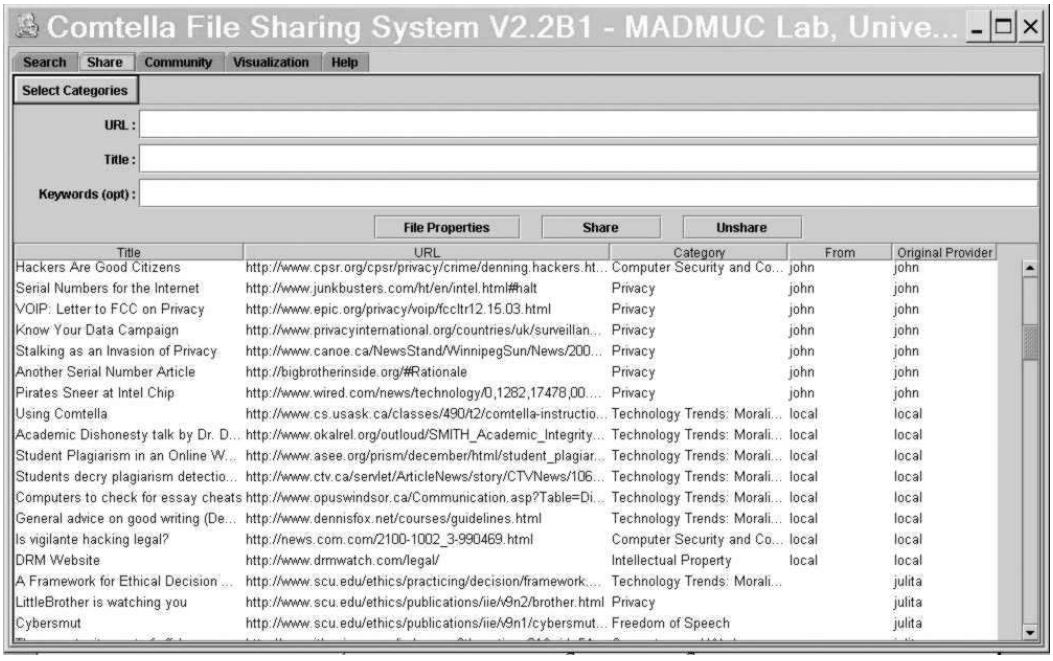

Figure 2: Comtella user interface, sharing of links view [26]

Edutella project is to provide the metadata services needed to enable interoperability between heterogeneous JXTA applications. This function does not exist in other p2p networks either and hopefully it will be introduced in the near future.

3.3 Organizing successful p2p based collaborative learning

The discussion and the experiences reported in the previous sections show that the p2p applications used today are not especially well suited for collaborative learning despite the similarity in conceptual architecture. The most important part of collaborative learning seems to be the social aspects of the collaboration and the equal participation of all students. The tools p2p environments can offer today do not support the social communication process enough but instead promotes unwanted behavior as segmentation of the task and competition between the students. There are also problems in the supporting of other group members in order to ensure that the result reflects the contribution of all the members of a group. Working collaboratively in a p2p environment might isolate the weaker members and promote the dominant behavior of stronger members. How can this be avoided?

Though the p2p environment offers great advantages in group work as it enables the members to participate asynchronously, when they have time and possibility, it does not remove the problems of heterogeneity and motivation among the group members. Thus special attention must be paid in ensuring this as we plan p2p based collaborative learning. The p2p environment also offers excellent possibilities to distribute the latest versions of reports and material found and produced to solve the task given as long as there is a well defined procedure how to do that and how to supply the metadata needed. The definition of the procedures used in the project must therefore be well defined. As the members of the group work independently of time and place the scheduling of the work process and the responsibilities of the group members must be carefully planned in order to ensure that the contribution of all group members are present in the final result of the group. This is where the teacher's role is extremely important. The teacher must produce and control the procedures and templates of the project.

The development of p2p software functionality is essential and can improve the collaborative behavior but as project tasks and student groups differ greatly there is no generic solution to p2p based collaborative learning. Functionality which improves the communication between the members of a group as email, chat, audio and video conferencing seems to be the most important toolbox to develop. The second toolbox to develop is the one supporting the project procedures and the scheduling of the activities with personal and group calendars and personal information systems. All tools that can increase motivation of the students are also essential. The tools proposed for the p2p collaboration do not have to be integrated in the same software package. Generally dedicated software is better than complex, multi functional, all purpose packages.

Some general rules for the arranging of successful p2p collaborative learning are:

1. Prepare the projects well considering content, procedures and motivation.
2. Set the goals high and supply templates and schedules for the solution or result.
3. Group the students according to diversity in knowledge, interest, skills and personality.
4. Insure, guide and supervise the social collaboration events in the beginning of the project.
5. Propose or supply p2p tools for different aspects of the collaboration.

6. Make examination criteria that will prevent or minimize the risk of 'free riding'.

By keeping these rules in mind the deficits of collaborative learning can be controlled and the learning results maximized.

4 Use case and experiences from it

During spring 2005 the author of this paper has conducted a small scale experiment in accordance with the literature findings. A second year course in programming that during the last three years has been web based was changed to project oriented collaboration learning. The individual tasks the students performed earlier were changed to greater and more demanding realistic projects from working life. The projects included full designing, planning and programming of commercial websites for internet shops. The product line sold by the shop could be freely selected by the students in order to increase motivation.

4.1 Use case arrangement

The students were grouped, based on a survey on personal skills, experience and interests, in five person groups. During the first phase of the first stage, which lasted for three weeks, collaborative design and planning was done at group meetings which were supervised by the teacher.

The groups worked according to a given schedule and the students communicated daily by using Morpheus p2p software to publish and exchange designs by using a naming convention. Morpheus was selected because several of the students involved had good experiences of using it and they were able to teach those students that had not worked with p2p software before, the installation and use of Morpheus. The discussions took place on a, for this purpose created, dedicated chat channel. In the second phase all the group members produced their own designs and plans for the website and in the third phase the results were compared using a given evaluation scheme. The resulting design was supposed to contain ideas and components from all the students work.

The fourth phase for the groups was to produce a written realization plan for the next stage of the project. The form of this documentation was fixed so that the tasks and the efforts of each student were described in detail. This was done in order to ensure that all members would participate and no 'free riding' would occur. The idea was further to avoid an unwanted parallel segmentation where one student could produce the majority of the code needed in the project. When this plan was ready it was approved by the teacher and then the students could continue to the next stage.

The project totally had five stages similar to the one described: planning, programming, testing, demonstration and evaluation. Every stage required the detailed planning and documentation of the next one in order to ensure the even participation of all group members and to get the approval to continue from the teacher. In all the phases of the work p2p tools were recommended to enable the collaboration and information exchange needed for the phase.

4.2 Use case results

The success of the experiment was judged based on a multiple choice survey performed after finishing the course on all the students that had participated. The findings can be summarized as followed.

- Most of the students (87 %) had enjoyed the collaborative work though they were skeptical when the course started.
- Most of the students (82 %) considered this course useful for them though they felt that they had not learned so much.
- Several students (69 %) thought that more functionality would have been helpful in the software used.
- Several students (64 %) appreciated the working methods they had learned during this course.
- Some students (27 %) were happy that they had learned to use chatting and p2p software which they did not use before.
- Some students (23 %) would have preferred a lecture based course as they felt they would have learned more efficiently.
- Very few students (8 %) admitted they had experienced 'free riding' in their group.
- Very few students (5 %) were unsatisfied with their grade from the course.

4.3 Use case analysis

The results show that students can find interest and motivation in collaborative work if it is successfully arranged. The students generally gave positive feedback as this course was the first one for them using this methodology and they experienced it as a different kind of course compared to the other courses given. Thus it reflects the students appreciation of change in the otherwise traditional educational methods, not necessary the advantages of the method used.

The grades were determined based on the documentation given by the groups and the quality of the website produced. The average grade of the course for this class was approximately the same as from earlier courses. It does however not show if the learning results are better here as the method of collaborative learning mainly improves the quality of learning not necessary the quantity. In order to prove this a separate examination test evaluating learning quality must be performed. This was not done in this case study but will be conducted in the future. A problem is that proper reference results for this course are not available as the course during the previous years have had an examination that was based on the students personal success in solving given programming exercises. This does not necessarily reflect the quality of learning either.

The criticism against the p2p tools used was quite widely spread. Generally the students did not see the p2p software as functional enough when they compared it to web-based educational software they had used before. This clearly

shows that the functionality of p2p software must be increased or it must be combined with other messaging and group software in order to meet the needs for collaborative learning. The case is another if audio and video material is widely used in a course. In that case the distribution of the material would greatly have benefited from the functionality of p2p software. This was not the case here and the size of the distributed material generally was very small compared to audio and video.

5 Conclusions

Collaborative learning is an educational method which works well in certain courses and develops critical thinking which leads to deeper understanding, analysis, synthesis and evaluation of a specific topic. It also promotes more social behavior and the working in groups which often is essential in working life. Combining collaboration and project based working gives a more realistic approach to education as tasks resembling real working situations can be given to the students and this can be used to increase the motivation.

Though the architecture of collaborative learning and peer-to-peer networks are alike the functionality of p2p software is not sufficient to enable real computer based collaborative work. By combining p2p, conferencing, messaging, group and project software a good collaborative educational environment can be created. This environment can however not replace the thorough planning and supervision of the students working process. The teacher's role is additionally to provide good working methods, templates and schedules for the projects in order to make them successful.

The students generally experience collaborative learning as an interesting and motivating form of education though they are suspicious considering the learning outcomes of the process. The process, methods and social aspects of collaborative learning are not considered as important as the technical knowledge and skills they expect their future employers to appreciate more. Thus collaborative learning should not be seen as a method that replaces lessons and laboraty work but merely complements or supports them.

Educational tools available today already have and certainly will adopt more of the features and functionality of p2p networks but the main problem in education is not the architecture but the functionality for the educational methods and needs. Thus special educational software will certainly exist to assist the learning process even in the future.

Further research and development is needed to provide the metadata needed for educational purposes in p2p networks. As a p2p network is decentralized and has no built-in information structure a special tool must be created in order to create the information structure and metadata needed in education. This is necessary to produce the infrastructure a peer-to-peer network needs to make the information useful for the students.

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