Deng, Y.-C., Lin, T., Kinshuk, Chan, T.-W. (2006) Component Exchange Community: A model of utilizing research components to foster international collaboration. *Educational Technology & Society*, 9 (3), 218-231.

Component Exchange Community: A model of utilizing research components to foster international collaboration

Yi-Chan Deng
Department of Computer Science and Information Engineering, National Central University, Taiwan
ycdeng@cl.ncu.edu.tw

Taiyu Lin and Kinshuk
Advanced Learning Technologies Research Centre Massey University, Palmerton North, New Zealand
t.lin@massey.ac.nz
kinshuk@ieee.org

Tak-Wai Chan
Research Center of Science and Technology for Learning National Central University, Taiwan
chan@cl.ncu.edu.tw

ABSTRACT

One-to-one technology enhanced learning research refers to the design and investigation of learning environments and learning activities where every learner is equipped with at least one portable computing device enabled by wireless capability. G1:1 is an international research community coordinated by a network of laboratories conducting one-to-one technology enhanced learning. The concept of *component exchange community* emerged as a means of realizing one of the missions of G1:1 - speeding up researches through exchanges of research components. Possible types of research components include software, subject matter content (learning objects), and methodologies. It aims at building a platform for fostering international collaboration, providing a novel way for the research work by an individual or laboratories to be accessed by the wider research community and users, and, in return, increasing research impacts of these researches. Component exchange community motivates maintenance of good quality documentation. This paper describes the concept and its model of component exchange community. Related models are compared and, as an illustration, a scenario of using component exchange community is given.

KEYWORDS

Component exchange, One-to-one learning technology, G1:1, eBay-like model

Background

One-to-one (1:1) technology enhanced learning (TEL) is defined as the design and investigation of environments and learning activities in which every learner is equipped with at least one computing device that is capable of offering the learning experience similar to that of one-teacher-to-one-student interaction. G1:1, pronounced as "G one one", is a research community (http://www.g1to1.org) that coordinates research teams conducting significant 1:1 TEL projects. In order to achieve this goal, the scope of the G1:1 initiative is broad; it includes research and development in fields that have potential to contribute to the realisation of the goal. Currently, six broad fields are identified: hardware, software, digital materials, theories for learning and teaching, activity models, and methodologies.

In order to harness the benefits of introducing mobility into learning environment (see Hsi, 2003), particular attention is paid to wireless-enabled hardware in the G1:1 initiative. G1:1 was in fact originally initiated by the organizers and some key participants of the first few IEEE International Workshops on Wireless and Mobile Technologies in Education (WMTE).

The hardware devices can be cellular phones, personal digital assistants, laptops, (which already have wireless communication capability), or graphing calculators, electronic dictionaries, Gameboys, and the like, which might be enabled by wireless communication capability one day. Over the next 10 years, it is anticipated that the pace of establishing the 1:1 experimental sites such as 1:1 classrooms at all educational levels or 1:1 informal learning locations such as 1:1 museums will be accelerating. Some of them, such as the One Laptop Per Child project (http://laptop.media.mit.edu), by the Media Lab of Massachusetts Institute of Technology, are deployment projects.

With support of wireless-enabled hardware, one-to-one TEL research brings about the concept of *seamless learning space*. It indicates the potential that one may learn in various learning scenarios (environments and learning activities). These learning scenarios vary over three dimensions: (1) places: classrooms, campus, outdoors, museums, forest, home, train, and so forth; (2) scale of number of people to learn with: none (learning alone), a small group, a whole class and the teacher, or a large online community; (3) learning activity models (or pedagogical models): intelligent tutoring, learning with cognitive tools (e.g. Lego), computer supported collaborative learning, digital game-based learning, and so forth. "Seamless" refers to the ease and quickness of switching from one learning scenario to another scenario while maintaining the continuity of one's learning. "Space" refers to the potential huge number of possible learning scenarios generated by varying over the three dimensions mentioned above (Chan, et al., 2006).

G1:1 is informal, yet, it connects to formal organizations such as Kaleidoscope (http://www.noe-kaleidoscope.org), The International Society of the Learning Sciences (ISLS, http://www.isls.org), Asia-Pacific Society for Computers in Education (APSCE, http://www.apsce.net), Artificial Intelligence in Education (AIED, http://www.ijaied.org), and potentially some others organizations in the future through overlapping membership and shared events. It has evolved over a series of events. There were three consequent workshops each year from 2002 to 2004. Then, in 2005, there were three G1:1 workshops and six panels in international meetings discussing G1:1. Except for the first one, all G1:1 workshops were held just prior to some international meetings.

At the core of G1:1 are a group of researchers who have been working in various research labs and centers in sub-areas of science and technology for learning. They perceive that the implications of the advent of wireless, mobile and ubiquitous technologies go beyond investigation of just another genus of new learning technologies, but an upcoming wave of technological innovations in both formal and informal learning, in which no nation avoids nor claims to be in the lead in research, technology, development, practice, deployment, and so forth of these changes (Roschelle & Pea, 2002; Hsi, 2003; Hoppe et al., 2003; Sharples & Beale 2003; Norris & Soloway, 2004; Roschelle et al., 2005; Liang et. al., 2005; Chan et al., 2006). There is an urgent need of putting together complementary strength and combining insights of different researchers as rapidly as possible to make a greater impact in the global context.

What does G1:1 do? Based on the belief that the high quality research is the basis of every intention and action of impacting 1:1 TEL, G1:1 intends to stimulate and promote high quality 1:1 research, at least to the extent that actively debate and critique what high quality research looks like; to set or attempt to set high standards for research outcomes, and support advancement of understanding.

G1:1 tries to inform advancements of 1:1 TEL, to raise the next direction of globally important learning challenges, establish an international research agenda, anticipate emerging drivers for educational changes by advanced learning technologies and their wider socio-cultural impact, and makes the impact of researches more visible and effective by aligning the momentum to the same direction.

G1:1 also attempts to increase the international sharing by serving as the key incubator for international collaborative research on designs, methods, strategies, software, and findings as well as exploring learning with similar technologies across multiple cultures. Besides, G1:1 is setting up a worldwide network of test beds so that a particular test bed can "see the universe" from the local and specific perspectives. This paper is an endeavor towards this mission of G1:1.

The preliminary concept of Component Exchange Community (CEC) was a part of the vision statement of G1:1 documented in late 2003 and a simplified version of that concept, Component Inventory, was proposed by Mike Sharple and Sherry Hsi in the second G1:1 workshop held in National Central University two days before IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE2004). The concept was implemented in a G1:1 website by Sharple and graduate students in National Central University.

The Component Inventory, serves as a portal and collects description of projects conducting 1:1 TEL projects. This information serving role, irrefutably important, is however limited by its similarity of content to individual projects' websites. The authors believe that the research community can be even better served by a sharing/collaborative model, which is similar to the success-proven e-Bay model in eCommerce. Component-exchange community (CEC) is an embodiment of such a collaborative model. The establishment of CEC also signals that the G1:1 initiative is difficult, if not impossible, to be achieved by an individual or a single research centre, but also the entire research community as a whole.

Objectives and Motivations

The objectives of CEC are the following:

1. Exchanging 1:1 research results, such as an 1:1 software, to be accessible to the wider G1:1 community;

2. Being the platform to foster 1:1 international collaborations; and
3. Encouraging high quality and collaborative documentation of some useful 1:1 research components.

There are two underlying assumptions of this effort. The first assumption is that researchers, in the academic world in general and in G1:1 in particular, are eager to share their research results, ideas and discoveries besides academic publications. Spreading research results is, in essence, a mission of academia. Traditionally, this is done by publishing books or papers in conferences and journals. Results of learning technology research do not only include ideas and discoveries, but could also be software systems or components. If the intellectual property has been recognised, the software, or part of the software, is ready to be publicized. The software could become an opportunity for collaborations and hence further its research impact if it can be used for research purposes by other 1:1 laboratories.

The second assumption is that there is a demand for reusable and/or modifiable research results in the advanced learning technology research community in general and G1:1 in particular, especially for graduate students. There are several advantages of this endeavour. First, it may reduce unnecessary efforts of re-inventing the wheel which cannot earn any credit any way. A laboratory, instead, can make their efforts more valuable by building upon what other laboratories have already done or develop alternative approaches. These research results are possibly the most up-to-date learning materials for other researchers, especially those who have just begun 1:1 research.

Although many researchers are eager to share their research outcomes, such as software systems, implementation documentations are often poor or even non-existent due to the higher priority of proof of concept than continual development or commercialization. The lack of good quality documentation hinders others from using research components that are already in existence. Furthermore, many countries/regions, owing to shortage of talents or resources, are in need of better/innovative products to improve their standard of education or living. In addition to this humanitarian benefit, it has been very long- and well-known belief which was explicitly pointed out by Florida (2005) that "*when talented people come together, their collective creativity is not just additive; rather, their interactions multiply and enhance individual productivity*".

The rapid growth of "weblogs" suggests that it may be possible that individual laboratories can publicize their research results, especially those such as software that cannot be published in the form of research articles or books. We can imagine an analogous situation in which every 1:1 laboratory is a "factory" for producing some research products. That factory can "sell" their products by having a "window" in the cyber world. The "sell" here may mean "call for using our software", "call for testing our software", "call for collaborating with us", and the like. Thus, unlike most of software sharing websites which follow Amazon-like model, CEC adopts eBay-like model.

The Amazon-like and eBay-like models are discussed subsequently in detail. The eBay-like model is further investigated from three different views that are: Dimension of Provider, Dimension of User and Dimension of Community, as shown in the section *Three dimensions of view to eBay-like model*. Graphical representations depicting the relations of different components, component versions and component contributors are employed to ease the search of components and attribute due credit to contributors. These graphs, called contribution-graph and pedigree-graph, are then discussed. A section is also presented about the prototype developed for CEC and an exemplary scenario showing how two different researchers can use CEC to their own benefit is depicted before the *Conclusion and Future Work*.

Related Works

There have been some centralizing efforts on global-scale research collaborations based on what we called the *Amazon-like model*. These include: the National High-performance computing and communications (HPCC) Software Exchange (NHSE), which is an Internet-accessible resource that promotes the exchange of software and information among those involved with high-performance computing and communications (Browne et al., 1995, 1998); SourceForge.net (http://sourceforge.net) which is the largest Open Source software development web site (Weiss, 2005); EduForge (https://eduforge.org), an open access environment designed for the sharing of ideas, research outcomes, open content and open source software for education; and Download.com (http://www.download.com) – the popular site to get freeware and shareware are all examples of the Amazon-like model.

Table 1 shows the comparisons of related works. The target of NHSE is especially for the research community whereas the SourceForge.net and Download.com are targeted for general purpose. EduForge is aimed at the field of education. The methodology of NHSE and Download.com are to collect software in their websites and that of the Source Forge and EduForge are to maintain projects in a centralized manner. Most of them use GPL (General Public License), LGPL (Lesser General Public License), or are classified as freeware or shareware to limit usage. They are a centralized model for product management and project management.

Table 1: Comparisons of related works

	Target	Methodology	Usage limitation	Model
NHSE	HPCC research purpose	Collect product in central site	GPL, freeware, shareware, …	Centralized product management
SourceForge	General purpose	Register projects in central site	GPL,LGPL …	Centralized project management
Download.com	General purpose	Collect product in central site	freeware, shareware, …	Centralized product management
EduForge	Educational purpose	Register projects in central site	GPL,LGPL …	Centralized project management

Definition of Component

It should be noted that the term "component" defined here is much less technically specific from that in software engineering literature (Booch, 1994; Szyperski, 1998; Sweller, 1998). In the area of learning technology, a 'component' usually refers to a piece of software, a unit of digital content material (in short, material), or perhaps a piece of hardware (probably together with some communication protocols). The type of component focused by CEC is somehow different from that of the industry. In CEC, the emphasis is placed on research components – components that bear value for the research community. Therefore, in addition to the usual types of component i.e. software, digital material and hardware, three more types of components are defined in CEC, namely: theory, activity model and methodology. These six types of components are defined in the following list:

- Components of theory: A theory is a logically self-consistent model or framework devised to explain a group of facts or phenomena, especially one that has been repeatedly tested or is widely accepted and can be used to make predictions about natural or social phenomena. In education and psychology, (learning) theories help us understand the process of learning. An example of components in this category is the Social Development Theory (Vygotsky, 1978).
- Components of activity models: An activity model is a schematic description of actors, tools, and their actions via some tools. A schematic description can be less rigorous than that described by a formal language, for example, Educational Modelling Language (Koper & Manderveld, 2004). Examples of activity models include the scaffolding and fading model in cognitive apprenticeship (Collins et al., 1989), the Jigsaw model of cooperative learning (Slavin, 1980), and reciprocal teaching model of peer tutoring (Palincsar & Brown, 1984; Palincsar et al., 1987).
- Components of methodologies: A methodology is a set of working methods consisting of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry. In other words, a methodology is a specific way of performing an operation that implies precise deliverables at the end of each stage of an activity model. An example of methodology would include specifying a set of principles and procedures in the design of a scaffolding tool to assist learning physics in senior high school level (Pea, 2004).
- Components of digital materials: Digital materials are digital files which can be launched by software components. These digital files are electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a software component and presented to the learner. More than one digital files can be collected together to build other digital files.
- Software components: Software components include but are not limited to:
  1. **Software applications** which are complete and stand-alone programs that can be installed and executed on one or a set of computational hardware devices.
  2. **Software objects** which are complete source codes or software libraries that represent one or a set of functions and can be quoted to reuse in developing another program. Software objects can be written in compiler languages such as object-oriented languages or interpreter languages.
- Hardware devices: Hardware devices include but are not limited to:

1. **Learning devices** which are hardware equipment used to facilitate the participation in learning activities. Learning devices can be purpose-specific devices such as response pads, graphic calculators, electronic English dictionaries, and pocket game machines. Other learning devices can be general-purpose devices such as cellular phones, personal digital assistants (PDAs), WebPads, Notebooks and Tablet PCs.
2. **Supporting devices** which are instructional equipments used to sustain learning activities taking place, such as EduCart (Deng et al., 2004), digital whiteboard, projector, learning management server, and so on.

A one-to-one learning scenario can be composed of a theory, an activity model, a methodology, a set of software components, a set of digital materials, and a genre of hardware devices as shown in figure 1. The collaborations between research teams can be contributed in different types of components to form a new one-to-one learning scenario.

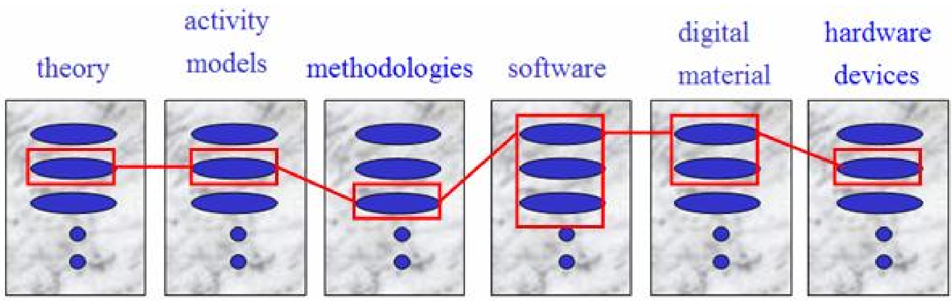

Figure 1: A example to composing six types of components

eBay-like Model

In this section, we propose an eBay like model for component exchange. In other words, the model is a central bulletin and peer contract model. In figure 2 shows, the CEC takes the role of a broker to trigger and promotes peer-to-peer collaboration. Research teams can submit their research components to CEC and they also can search to find out their collaboration candidates in CEC and request to create a Component Usage Agreement. The two parties of a Component Usage Agreement are called the *Requestor* and the *Requested*.

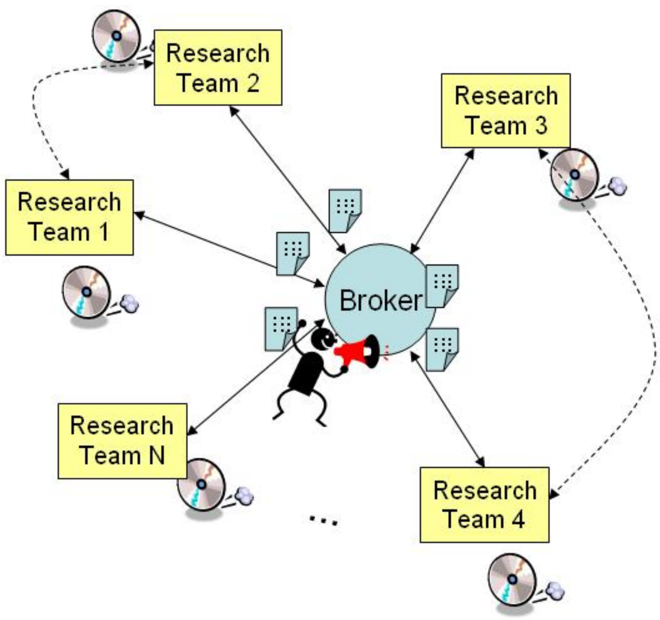

Figure 2: eBay-like model

Once a candidate component is found, the *Requestor* submits a request to the *Requested* expressing intention to create a *Component Usage Agreement* so that the *Requestor* can use one of the components in CEC provided by the *Requested*.

The Component Usage Agreement consists of zero to many clauses. Each individual clause represents a condition that either the *Requestor* or the *Requested* wish for. Both the *Requestor* and the *Requested* are entitled to initiate (add) or modify clauses before the agreement is finalized. Some default clauses are initially available but are optional. Some of these default clauses are as follows:

- The *Component Owner* agrees to provide any missing information or objects that was unintentionally not incorporated in the original Component.
- The *Component Owner* and the *Component User* agree to jointly own the copyright of the research data resulted from the use of the Component.
- The *Component Owner* and the *Component User* agree to grant each other the right to initiate publication of the research result from the use of the Component.
- The *Component Owner* and the *Component User* agree to include the representative(s) from the other party in the author list if the research results from the use of the Component are published.
- At the close of the study, the *Component User* will provide the *Component Owner* with a final and complete dataset gathered in the research in which the Component was involved.

The change of terms, from *Requestor* to *Component User* and from *Requested* to *Component Owner*, takes place when the status of the *Component Usage Agreement* is finalized.

Depending on whether the initiator or the last modifier made the last change to the clause, each clause is categorized as either Requestor-initiated/modified-clause (Requestor- clause) or Requested-initiated/modified-clause (Requested-clause). Each clause has to be agreed by both parties before the finalization of the agreement, for example, when the *Requestor* agrees with all Requested-clauses, he/she can finalize the agreement; and the same applies to the *Requested* with all Requestor-clauses.

The following is an example to illustrate some of the clauses.

Three Dimensions of Viewing CEC

Members of CEC are of two types: *providers* and *users*. A provider of a component is a research team who offers the component to the community. A user of a component is either a *collaborator,* who is a research team collaborating with the research team providing the component, or a *consumer,* who is a teacher, learner, or administrator and uses the component in teaching or learning activities.

This section discusses three dimensions of viewing the eBay-like model: the Dimension of Providers, the Dimension of User and the Dimension of Community. There are three different levels of sharing in each dimension, as described below, to allow providers and users of educational computing research community to have more choices to share or collaborate with others.

Three Levels of Each Dimension

There are three levels in each dimension. The first level is simple and requires the least effort for each dimension whereas the third level is the most complex and requires the most effort for sharing and using. There are inevitable conflicts between the needs of providers and users. The users always require more resources, but the providers may not have the time or resources to cater for what the user asks for. Different levels provide more options for both providers and users.

However, quality control is always an issue for sharing. A contribution labelling and management mechanism is developed and is tailored to the particular needs and nature of the research community. Contributions are labelled by different levels- level 1 is the simplest and level 3 the most complete.

Component contributor's self-assessment is the easiest and earliest quality label that could be obtained. Anyone who wishes to share his/her research components and contribute them to the CEC and the rest of research community can simply refer to table 3 and table 4 to label the provided components. In this manner, the component provider is not required to provide documentation, user support, and so on to the fullest level which in fact may not be needed by the users.

The rest of the community can also have their say about the quality label of components. A voting mechanism allows the user and others to determine the authenticity of the initial data input by the providers.

Dimension of Provider

From the viewpoint of the provider, a simple three-tier classification and basic attributes are used to explain the different levels of components and provider (Table 2).

Table 2: Check-lists of provider

	Level 1	Level 2	Level 3
User manual	primitive	complete	complete with case studies
Open source code	none	a little	many
Consultant	asynchronous (e-mail)	synchronous (telephone, video conferencing)	face-to-face (students /developers exchange)
Development document	none	thesis / technical report	detail
Central info updating	none	sometimes	synchronous
Release constrains	just one time	by contract	no limitation

Table 3 constitutes an example of basic requirements for providers. For example, the correction-type component is at its testing stage (beta version) and requires testing, debugging and improvement. The component provider will provide at least *user manual* and *central info updating* attributes to level 3 (i.e. comprehensive user manual, total accessibility for updates/patches) to allow users to test the components and access the latest component information. The other attributes might be still at level 1.

Table 3: Examples of component type

	Correction-Type Component	Discovery-Type Component
User manual	complete with case studies	Complete
Open source code	none	Many
Consultant	asynchronous (e-mail)	face-to-face (students /developers exchange)
Development document	none	Detail
Central info updating	synchronous	Sometimes
Release constrains	just one time	no limitation

If the research component is of discovery-type, then it is stable but the provider needs to see how it works and discover its potential applications. The provider will offer *user manual* and *central info updating* attributes to level 2. The *user manual* of level 2 is not expected to have the examples of case study so the user would not be confined to only the examples shown on the user manual and would discover more creative ideas. On the other hand, as the component is quite stable, *central info updating* does not need to be done frequently. The other attributes such as *open source code*, *consultant*, *development document* and *release constrain* can also be set to level 3 to attract more suitable users for collaboration.

From the above examples, it can be seen that the provider can select different attributes at different levels based on various development stages, on the extent of producing different attributes and on expected results of his/her research component.

Dimension of User

Similar to dimension of provider, a simple three-tier classification (Table 4) and its basic attributes are used to explain different kinds of users (Table 5). For example, a use-only user might need all attributes at level 1 (none of the attributes is needed). The component will of course be quite limited, but will suffice the need of the use-only user.

Table 4: Check-list of user

	Level 1	Level 2	Level 3
Document	none	error correcting	localization and new case study
Code development	none	modification	integration
Development human resource	none	student	development team
Feedback	none	suggestion	paper

A feedback-type user, who agrees to provide feedback after using the component, is required to have *feedback* and *document* attributes to level 3 and the other attributes to level 1. But a developer-type user, who wishes to enter a co-develop relationship with the provider, will need to have *code development* and *development human resource* attributes at level 3 and feedback and document attributes at level 2.

Table 5: Examples of user type

	Use-Only User	Feedback-Type User	Developer-Type User
Document	Level 1	Level 3	Level 2
Code development	Level 1	Level 1	Level 3
Development human resource	Level 1	Level 1	Level 3
Feedback	Level 1	Level 3	Level 2

From the above examples, we can see how users can classify themselves and how providers can find their potential collaborators.

Dimension of Research Community

The Dimension of Research Community is the identifying feature of the eBay-like model. Through the community, different kinds of events can be organised to promote research collaboration and further participation among existing members and to attract new members. One of the important roles of the community is a broker of sharing and exchange. If one uses Google to find a collaborator, one would need to laboriously search, filter, identify, and request for permission. Whereas the research community offers a formal channel that users can search for components; advertise their need of certain components; and publicize their own components – all in a contextualised manner.

As opposed to the once-off collaboration between two research teams for a single task, CEC employs a contribution-graph and pedigree-graph to allow multi-team- and multi-version- collaboration to take place. Detailed discussion of these two graphs is presented in the next section.

The community, as a monitoring body, can also prevent aberrant or illegal behaviours from its members such as virus spreading or commercial advertisement; as a managing body, it can provide and manage membership registration and identification; and as a marketing body, can work with other international agencies or events to promote the community itself.

The Research Community is also an arena for achievement recognition. Excellent component could be selected by experts periodically and a Seal of Recognition given to the contributing research team. This can foster an atmosphere of constructive competition whereby developing higher quality components are encouraged.

The community itself is an attraction for enhancement. The more its members and the greater its number of components are likely to appeal, the more new members registrations and component submissions will increase. The higher quality the community's components are, the more likely that they are going to draw in further high quality research components. The positive snow-ball effect is the unique feature expected to differentiate a community-based approach and a randomly occurring approach of research collaboration in the long run.

e-Bay Model vs. Amazon-model

A comparison with the Amazon-like model can help understand the e-Bay model further. Table 6 below shows the differences between these two models. As a centralized model, the Amazon-like model has to face all the users and is expected to have its components attain a certain level of quality in order to be able to exchange and share. However, as a peer-to-peer model, the eBay-like model only needs to stress a clear explanation of the current status of research products to its user, whom is usually a single user at a time, and not on the quality of the product. If the other researcher or research team accepts the quality, then collaboration or exchange can be conducted. With regard to the collaboration between the *Provider* and the *User*, in the Amazon-like model, there is little collaboration between the *Provider* and the *User*. But in the eBay-like model, there is a lot more collaboration between the *Provider* and the *Provider*; and the *Provider* and the *User*. The Amazon-like model usually follows different kinds of standards to appeal to a bigger audience. But in the eBay-like model, if the two parties come to an agreement and they follow some simple rules, they can exchange and collaborate. In the Amazon-like model, there are a lot more issues and policies to consider, for example, which standard to follow or which development platform to use, etc., whereas the eBay-like model places more concern for issues such as getting the maximum benefit for two collaborating parties.

Table 6: Comparisons of Amazon-like and eBay-like model

Amazon-like model	eBay-like model
• Well quality control	• Easy to contribute
• Less collaborations between users and providers	• More collaborations between users and providers
• Standard rules	• Easy to get peer consensuses & some basic rules
• More policy issues	• More mutual benefit issues

Contribution-graph and pedigree-graph

Another issue that researchers are generally concerned about is credit. The credit is the user can recognize and acknowledge the provider. So, we use a contribution-graph and a pedigree-graph to record the data of every component. Each node on the graph depicts a component. A link records the change between two components. A contribution-graph is mainly used to record the entire history of a component right from its initial node. A pedigree-graph is used to output all the links and nodes of a particular component. Below we make a detailed description of the two types of graphs.

Contribution-graph

The contribution-graph is designed for tracing the history of component and to give credits to authors. It depicts all the links between components that have a contribution relationship.

An exemplary contribution graph is shown in figure 3. In the figure, Research Team 1 (RT1) revises component A to make another component B and registers it under CEC. RT2 has needs for component B to use it in PDA. Hence, they will modify component B to make another component C for use in PDA. Therefore, Figure 3(a) shows the contribution-graph for Component C. Figure 3(b) provides description of contribution of the two research teams, RT1 and RT3, in integrating components B and D to bring about a new component that has new benefits for both the research teams. In this scenario, teams RT1 and RT3 will jointly integrate components B and D to make a new component E.

Pedigree-graph

The pedigree-graph is designed to show the whole picture of a component. It not only shows the contribution links of the older generation, but also all the links and nodes of the previous, current and following generations. This is expected to help the users in understanding the initial and subsequent developments of a particular component and in helping them find a suitable component or collaborator.

Figure 4 shows the pedigree graph of component B that was discussed in the previous section.

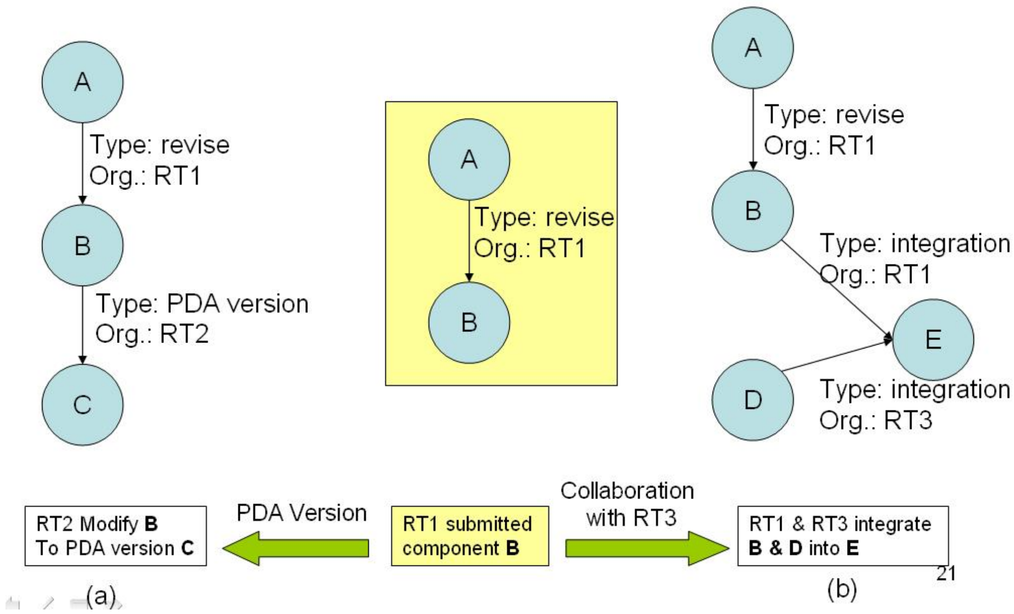

Figure 3: Examples of contribution-graph

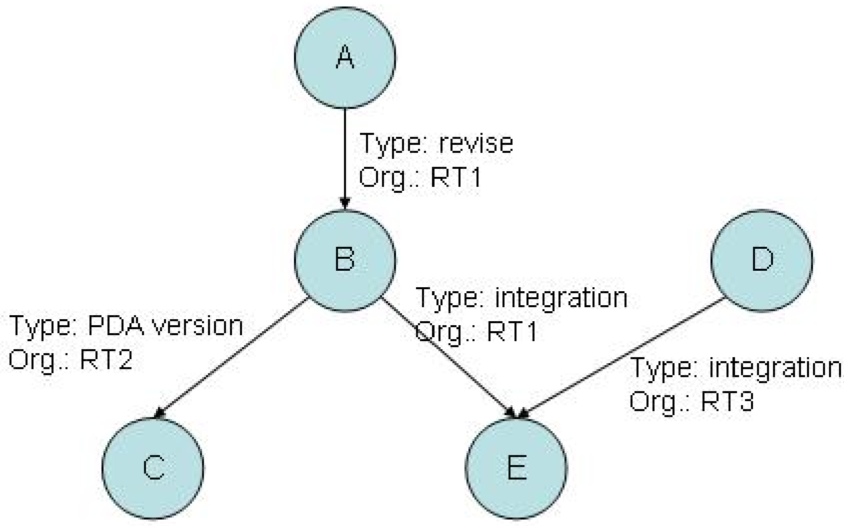

Figure 4: Example of pedigree-graph

Implementation of CEC

A prototype CEC has been implemented and deployed at the following URL: http://cec.g1to1.org/cec. Technically, the CEC website is developed using PHP and MySQL. The website (Figure 5) embodies the ideas and provides the services presented in this paper.

It needs to be pointed out that unlike the software download site introduced earlier, CEC is membership-based. Its membership is only granted to those who have contributed one or more components to CEC or who is willing to contribute to the improvement of existing components, for example, offer to evaluate the component in a new context. Only members can request to create a Component Usage Agreements with other member(s). This mechanism is particularly designed for research community. CEC membership, like the creditability of any researcher, is to be valued and built on honest contributions.

Strict protocols are also in place, as the conditions to use the services provided ensure the quality of operation in the CEC.

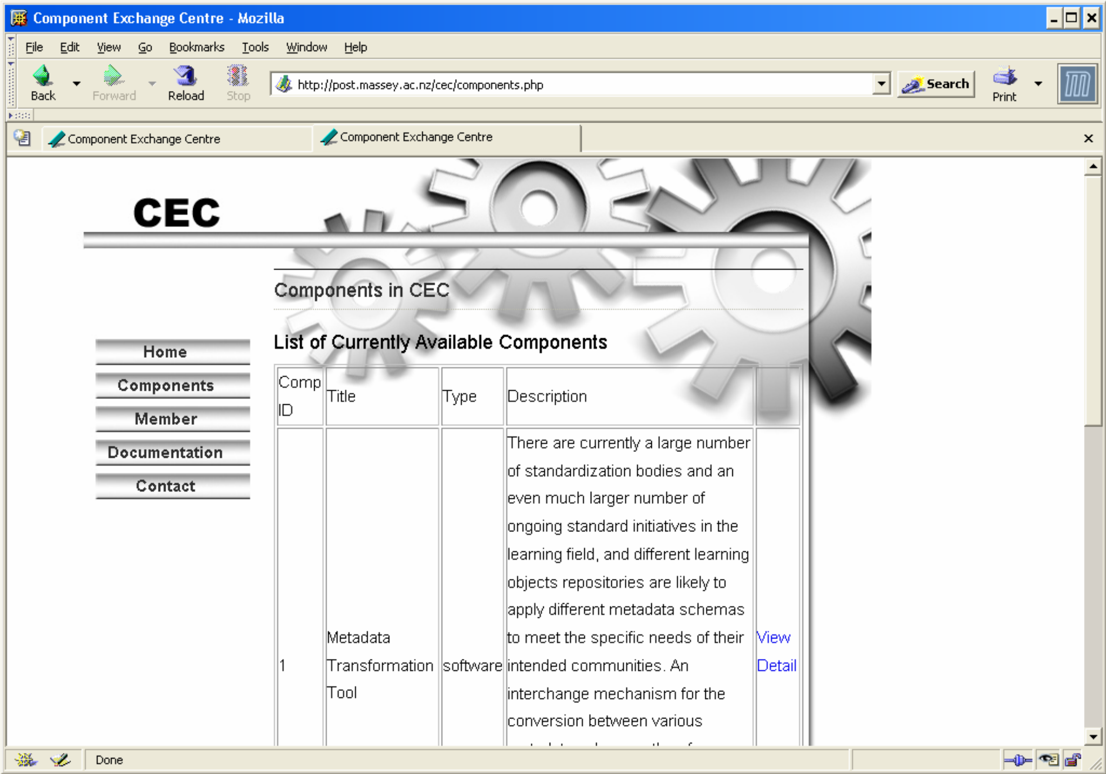

Figure 5: Website of Component Exchange Community (CEC)

A Scenario of Collaboration

The Center of Learning at National Central University (CL@NCU) submits Digital Classroom Environment Test bed as a component in the CEC system. (Huang et al., 2001; Liu et al., 2003; Liang et al., 2005; Deng et al., 2005) in the CEC system.

A research team "S" in the CEC from Singapore (S@Singapore) finds the Digital Classroom Environment Test bed component which partially meets their particular research requirements. S@Singapore contacts CL@NCU and makes a request for collaboration. The Requirement lists of S@Singapore are as follows:

- To provide the Datalogger WebPAD interface
- Device control (push/pull/control…)
- Group activity (co-construct group project report)
- Experiment data collections
- Formative assessment
- To integrate Science Project-based Learning System and Digital Classroom Environment (DCE) to create a new product namely SCL-DCE.

Then both parties modify the template of *Component Usage Agreement* in CEC to finalize the contract. The details of the contract are as follows:

1. The CL@NCU agrees to provide any missing information or object that was unintentionally not incorporated in the DCE.
2. The CL@NCU and the S@Singapore agree to jointly own the copyright of the research data resulted from the use of the SCL-DCE.
3. The CL@NCU and the S@Singapore agree to grant each other the right to initiate publication of the research result from the use of the SCL-DCE.
4. The CL@NCU and the S@Singapore agree to include the representative(s) from the other party in the author list if the research results from the use of the SCL-DCE are published.
5. At the close of the study, the S@Singapore agrees to provide the CL@NCU with a final and complete dataset gathered in research in which the SCL-DCE was involved.
6. The S@Singapore agrees to send two students to CL@NCU for 2 months to get the training required for integration.
7. The SCL-DCE is limited to be used in S@Singapore and CL@NCU.

8. New contract is needed for any business use.

After signing the contract, the S@Singapore sends two students to CL@NCU and begins the training program. Two month later, these students take the unfinished integrated product SCL-DCE back to S@Singapore. The S@Singapore keeps contact with CL@NCU and continues to finish the integration. The S@Singapore also updates the user manuals of SCL-DCE. The CL@NCU updates the DCE development documents and updates the SCL-DCE contribution-graph in the CEC. Then the S@Singapore starts experiment with SCL-DCE. Finally, CL@NCU and S@Singapore co-author a paper to report the results.

Discussion

The contribution of a member in CEC can be recognized by providing (sort of informal 'publishing'), enhancing (e.g. documenting, extending, etc.), or testing of a component. Thus CEC can help trigger more collaboration among international research teams. Through the process, each participating team may strengthen their work and gain more widespread influences through joint publications. Besides, a practical incentive for these collaborating research teams is that they may apply for international bilateral collaborative research funding.

One may ask: why do not use Google to find a collaborator as most researchers will list their on their homepages these days? Google can be regarded as an ad-hoc mode in this perspective because one may search, filter, identify, and then send emails to potential collaborators. A potential difficulty of this approach is the lack of vocabulary (keywords) of intentional research collaboration intention such as "document my component," "call for test my component," "call for collaborators," and the like, in the searching process of components and collaborators. Even if one finds an interested component, the intention for collaboration of the provider of that component is not known. This is contrary to CEC. CEC is a channel for component providers and adopters to advertise their needs, and hence their intentions for collaboration and the specific requirements or details of their preferred collaboration modes are made explicit.

There was debate on the priority of the six types of components in CEC though no consensus was reached. We believe experience and time of the working CEC would tell the answer. Nevertheless, G1:1 website provides a web-based Component Inventory in which there are: Centre for Educational Technology and Distance Learning (CETADL), University of Birmingham, Center for Learning Technology, National Central University, Taiwan, and The University of Tokushima, Japan. CEC can be regarded as an extension of this Component Inventory by specifying collaboration intentions and building an active community.

Although it is still unknown whether the ambition of the One Laptop Per Child project initiated by the Media Lab of Massachusetts Institute of Technology for providing a $100 laptop to millions of schoolchildren in developing countries (http://laptop.media.mit.edu) can be fulfilled, the $100 laptop hardware itself can be regarded as a hardware device component in CEC. Once a critical mass for a *virtuous cycle*, in which momentum gathered by increasing number components further develops its impact and attracts more people to contribute to CEC, is reached, it then makes possible the vision of abundance of educational components ready to go together with the $100 laptop to benefit those who are in need.

Summary

Component exchange community (CEC) has sprung from the vision of G1:1 which aims to support increased international sharing and coordination of one-to-one learning technology. CEC has its focus on learning technology components at their earlier (research) stage and provides a semi-formal mechanism similar to a marketplace where sellers (component providers) can provide specifications (by using Table 3, i.e. provider checklist) of their products. The buyers (component requestor/experimenters) can make offers (by using Table 4, i.e. user checklist) to obtain the products. Idiosyncratic requirements can be added using clauses in the *Component Usage Agreement* in addition to what are already mentioned in the provider and user checklist. In this manner, greater flexibility is achieved.

It is the hope of the authors that the establishment of CEC can accelerate global collaborative research on learning technology by achieving the following:

- Accessibility: research works of individual researchers or research teams can be more accessible to the global research community and users;

- Quality: researchers with higher possibility of sharing and collaboration in mind can develop better quality components and documentations;
- Synergy: where research components can be creatively assembled; and
- Utilisation: those users in need can obtain what they require using non-monetary rewards (e.g. carrying out an experiment of a theory, or testing a beta-version component).

CEC is unique in its three-levels of exchange model, which provides more options for different contributors' and users' needs, and its contribution graph, which is taken from a family tree analogy, showing merger (marriage) of components and where contribution acknowledgements are visible even after several new versions (generations) of any research components. Its pedigree-graph shows the blood-line of each component. This information is particularly beneficial when two researchers wish to enter an agreement to further develop a specific component.

CEC is an ongoing project based on the previous attempt of the Component Inventory proposed by Mike Sharples and Sherry Hsi. CEC website has already been set up to validate this unique concept by testing and refining process (http://cec.g1to1.org/cec). The authors would like to invite those who are involved and interested in learning technology to contribute and use CEC.

Acknowledgement

The authors would like to thank the participants of G1:1 workshop in WMTE 2005, Japan for their comments and suggestions. The authors would also like to thank Amy Chen, Emily Ching, Rosa Paredes Juarez, Jitti Niramitranon and Nobuji Saito Vazquez for their valuable inputs to the various organisational specification of the CEC.

References

Booch, G., (1994). *Object-Oriented Analysis and Design with Applications*, Addison-Wesley, Reading, MA.

Browne, S., Dongarra, J., Green, S., Moore, K., Rowan, T., Wade, R., Fox, G., Hawick, K., Kennedy, K., Pool, J., Stevens, R., Olson, B., & Disz, T. (1995). The National HPCC Software Exchange. *IEEE Computational Science and Engineering, 2* (2), 62-69.

Browne, S., Dongarra, J., Horner, J., McMahan, P., & Wells, S., (1998). The National HPCC Software Exchange (NHSE). *D-Lib Magazine, 4* (5), retrieved June 30, 2006, from, http://www.dlib.org/dlib/may98/browne/05browne.html.

Chan, T. W., Roschelle, J., His, S., Kinshuk, Sharples, M., Brown, T., Patton, C., Cherniavsky, J., Pea, R., Norris, C., Soloway, E., Balacheff, N., Scardamalia, Marlene., Dillenbourg, P., Looi, C. K., Milrad, M., Hoppe, U., Nussbaum, M., Mizoguchi, R., Ogata, H., McGreal, R., & G1:1 members (2006). One-to-one Technology Enhanced Learning: An Opportunity for Global Research Collaboration. *Research and Practice in Technology Enhanced Learning, 1* (1), 3-29.

Collins A., Brown J. S., & Newman S. E. (1989). *Cognitive Apprenticeship: Teaching the crafts of reading, writing and mathematics.* In Resnick, L. B. (Ed.), *Knowing, Learning and Instruction*, Hillsdale, NJ: Lawrence Erlbaum, 453-494.

Deng, Y. C., Chang, S. B., Chang, L. J., & Chan, T. W. (2004). EduCart: A Hardware Management System for Supporting Devices in a Classroom Learning Environment. In *Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education* (WMTE 2004), Taiwan, 177-181.

Deng, Y. C., Chang, S. B., Chang, B., & Chan, T. W. (2005). DCE: A One-on-One Digital Classroom Environment. In *Proceedings of Artificial Intelligence in Education*, Amsterdam, 786-789.

Florida, R. (2005). Where it's at. *New Scientist*, 29 October 2005, 43.

Huang, C. W., Liang, J. K., & Wang, H. Y. (2001). EduClick: A Computer-supported Formative Evaluation System with Wireless Devices in Ordinary Classroom. In *Proceedings of ICCE 2001*, 1462-1469.

Hoppe, H. U., Joiner, R., Milrad, M., & Sharples, M. (2003). Guest editorial: Wireless and Mobile Technology In Education. *Journal of Computer Assisted Learning, 19* (3), 255-259.

Hsi, S. (2003). The Electronic Guidebook: A Study of User Experiences Mediated by Nomadic Web Content in a Museum Setting. *International Journal of Computer-Assisted Learning, 19* (3), 308-319.

Koper, R., & Manderveld, J. (2004). Educational modelling language: modelling reusable, interoperable, rich and personalised units of learning. *British Journal of Educational Technology, 35* (5), 537-551.

Liang, J. K., Liu, T. C., Wang, H. Y., Chang, B., Deng, Y. C., Yang, J. C., Chou, C. Y., Ko, H. W., Yang, S., & Chan, T. W. (2005). A few design perspectives on one-on-one digital classroom. *Journal of Computer-Assisted Learning, 21* (3), 181-189.

Liu, T. C., Wang, H. Y., Liang, J. K., Chan, T. W., Ko H. W., & Yang, J. C. (2003). Wireless and mobile technologies to enhance teaching and learning. *Journal of Computer Assisted Learning, 19* (3), 371-382.

Norris, C., & Soloway, E. (2004). Envisioning the handheld-centric classroom. *Journal of Educational Computing Research, 30* (4), 281-294.

Palincsar A. S., Brown A. L. (1984). Reciprocal Teaching of Comprehension- Fostering and Comprehension-Monitoring Activities. *Cognition and Instruction, 1* (2), 117-175.

Palincsar A. S., Brown A. L., & Martin S. M. (1987). Peer Interaction in Reading Comprehension Instruction. *Educational Psychologist, 22* (3&4), 231-253.

Pea, R. (2004). The Social and Technological Dimensions of Scaffolding and Related Theoretical Concepts for Learning, Education, and Human Activity. *Journal of the Learning Sciences, 13* (3), 423-451.

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology, 1* (1), 145-168.

Roschelle, J. Patton, C. Brecht, J., & Chan, T. W. (2005). The Context for WMTE in 2015. In *Proceedings of the 3rd IEEE International Workshop on Wireless and Mobile Technologies in Education* (WMTE 2005), Japan, 112-119.

Sharples, M., & Beale, R. (2003) A technical review of mobile computational devices. *Journal of Computer Assisted Learning, 19* (3), 392-395.

Slavin R. E., (1980). Cooperative Learning, *Review of Educational Research, 50* (2), 315-342

Sommerville, I., (1998). *Software Engineering*, Reading, MA: Addison-Wesley.

Szyperski, C., (1998). *Component Software*, Reading, MA: Addison-Wesley.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257-285.

Vygotsky, L. S. (1978). *Mind in Society*, Cambridge, MA: Harvard University Press.

Weiss, D. (2005) Quantitative Analysis of Open Source Projects on SourceForge. In *Proceedings of the 1st International Conference on Open Source Systems* (OSS 2005), Genova, Italy, 2005.