Chapter 10
Computer-Supported Collaboration Scripts

Perspectives from Educational Psychology and Computer Science

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Abstract Students are often at a loss for what to do or have inadequate ideas of how to build knowledge collaboratively through computer-supported collaborative learning (CSCL). Facilitating specific CSCL processes by providing learners with computer-supported collaboration scripts is regarded as a promising approach. Implemented in CSCL environments, computer-supported collaboration scripts specify, sequence and distribute roles and activities. Scripts are intended to scaffold activities that students could not yet engage in on their own. One of the main challenges of this approach for realising effective CSCL is the continuous adaptation of scripts to learners' needs and knowledge. Efforts to specify and formalise script components and mechanisms have led to an integrative framework for computer scientists, educational scientists and psychologists of what constitutes computer-supported collaboration scripts as well as a growing library of prototypical CSCL scripts.

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10.1 Challenges of Implementing Effective Collaborative Learning

Collaborative learning is a central component of many current theoretical and practical approaches to learning and instruction and is assumed to foster specific learning processes and outcomes. Having ownership of their learning processes,

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collaborative learners are expected to elaborate and share knowledge with peers and thus acquire and become able to apply domain-specific knowledge as well as attaining soft outcomes, such as self-esteem, motivation, and social skills (Johnson & Johnson, 2002; Lave & Wenger, 1991; O'Donnell & King, 1999; Slavin, 1995; Vygotsky, 1978). However, implementing effective collaborative learning in schools and universities today is a challenging task. Imagine a university teacher giving an introductory lecture to about 100 students on some basic approaches in educational psychology, such as theories of attribution. Beyond the lecture itself, in which the basic theories should be introduced, the lecturer wants the students to learn how to apply the psychological theories to single problem cases collaboratively, including additional literature in their work. Therefore, students are expected to learn collaboratively through solving complex problems. Guiding a large number of students through a problem-oriented learning environment including facilitation of specific activities and providing feedback is a challenging task. Throughout this chapter, this example will be revisited to outline how computer-supported collaboration scripts can help to realise effective collaborative learning scenarios.

Computers can support collaborative learning through a number of communication and representation tools, such as asynchronous discussion boards or wikis, creating a virtual space for students to work on learning tasks together (Chapter 1; Stahl, Koschmann, & Suthers, 2006). Yet merely assigning a collaborative task and providing learners with communication tools may not suffice to establish effective (computer-supported) collaborative learning. Teachers therefore need to scaffold learners in building and maintaining shared understanding (see Chapter 1; Dillenbourg, 1999; Fischer & Mandl, 2005; Mäkitalo, Weinberger, Häkkinen, Järvelä, & Fischer, 2005; Weinberger, Stegmann, & Fischer, 2007b). As educational psychologists and computer scientists, we must investigate ways of supporting both learners and teachers in reaching their goals in collaborative learning and teaching.

Computer-supported collaboration scripts (CSCL scripts) are an approach to setting up and facilitating effective collaborative learning and can be defined as a specific type of instructional support or scaffold. There is a variety of scaffolding techniques for very different purposes (see Quintana et al., 2004). What makes collaboration scripts special (both for face-to-face groups and for computer-mediated groups) is their focus on the collaboration process between two or more group members. That is, collaboration scripts do not necessarily provide guidance on a conceptual level (for example by providing content-specific prompts such as "Explain why ball A moved slower after it hit ball B"), but rather on a (collaboration) process level (e.g. "Listen to your partner's explanation and think about counterarguments for her explanation").

On a macro-level, CSCL scripts can structure and link lectures, individual and collaborative learning phases in face-to-face or in computer-mediated environments. For instance, the university lecturer in the above example might design a script that coordinates the distribution of resources between the lecture and an online environment. Additional literature that is downloadable in an online course management system could be identified in the lecture. After handing out specific reading and writing assignments to individual learners, groups of three or four students could be formed. In these groups, learners could be assigned the task of collaboratively analysing problem cases on the basis of theoretical texts they have read and initial ideas they have noted down individually.

On a micro-level, CSCL scripts scaffold specific collaborative learning processes and provide learners with more or less detailed instructions concerning the types and sequence of different activities and roles they are expected to perform during collaboration (Kollar, Fischer, & Hesse, 2006). Unlike early scripting approaches, CSCL scripts may be designed flexibly to guide learners to communicate and share representations of their knowledge. CSCL scripts could be adapted by learners as well as by teachers to fit specific pedagogical scenarios and goals.

Besides supporting the implementation of scripts in a specific learning environment, computers can also support the design and adaptation of scripts to different learning environments. In the university lecture example, specific interaction patterns could be facilitated by assigning different roles to the students, such as case analyst and constructive critic. These roles in turn can be supported by sentence starters provided in asynchronous discussion boards within the CSCL platform, such as "The most important theoretical concepts that can be applied here are . . ." or "What I did not understand was. . ." (see Weinberger, Ertl, Fischer, & Mandl, 2005).

For the remainder of this chapter, the university lecture example will be used as a reference when synthesising recent theoretical, empirical and design-related developments in educational psychology and computer science leading to the specification and formalisation of CSCL scripts. The following sections elucidate how CSCL scripts can be designed to facilitate learners' transition from other- to self-regulation and outline a vision for future research and practice.

10.2 Outlines of a Script Theory of Collaborative Learning

An essential aspect of most forms of collaborative learning is that peers verbally negotiate with each other about how to solve specific learning tasks, with the goal of acquiring knowledge individually. Learners' interaction processes are therefore assumed to be related to cognitive processes of learning in "spirals of reciprocity" (Salomon & Perkins, 1998). In constructing explanations and arguments, learners outline and thereby restructure their individual knowledge in a linear form. Reciprocally, learners hear their peers' arguments, which may comprise additional resources in solving a task and prompt learners to reply and construct new (counter-) arguments. Learners who are able to balance arguments fairly will thus acquire knowledge individually, which in turn enables them to execute cognitive activities on a higher level (Schwarz, Neuman, Gil, & Ilya, 2003).

10.2.1 Internal and External Scripts

One reason for the wide variation in students' learning and academic success lies in different patterns of socialisation in the classroom (e.g. teacher–student or student–student interactions, actual instruction, teacher's expectations; Brophy & Good, 1986). Students may know little about how to collaborate and learn together. For instance, learners often lack procedural knowledge of how to construct and interpret arguments. This procedural knowledge has been conceptualised as *internal scripts* (Kollar, Fischer, & Slotta, 2007).

From a cognitive psychology perspective, internal scripts are understood as a particular type of cognitive schemata: cognitive constructs that help individuals understand and act in meaningful ways in dynamic events (Kolodner, 2007; Schank & Abelson, 1977). In other words, individuals have already existing expectations, a set of beliefs and a repertoire of possible actions to choose from in certain situations. If the situation is new, individuals refer to similar past experiences and modify their behaviour accordingly to better fit the new situation. From a schema theory perspective, collaborative learners would share some more or less elaborated knowledge on what events and activities could be expected during the learning process. For instance, some learners might expect to communicate with their partners and participate more or less equally in working on a joint task. Depending on the novelty of the situation, learners may also have more elaborated scripts and sub-scripts, such as introducing yourself and your perspective on the task, asking questions, giving explanations, providing counterarguments, synthesising different opinions, documenting group processes and outcomes (with specific artefacts) and coming to a joint conclusion.

Contrary to Schank and Abelson's (1977) initial conceptualisation, scripts are not rigid plans that determine processes from start to end (cf. Suchman, 1988, 2003), but culturally shared knowledge represented within the individual mind about abstract events and activities that take different concrete forms in single instances of collaborative learning events. As a result, internal scripts are postulated to be flexible enough to adjust to changes in the collaborative situation as well as to be applied in different collaborative learning situations. As CSCL may pose a particular novel situation for most, learners' internal scripts may be less elaborated, lack specific sub-scripts or bias learners' perceptions and lead to inadequate activities with respect to the collaborative learning goals.

As internal scripts often appear to be fragmentary and even dysfunctional, collaborative learning has been facilitated with experimenter-generated (O'Donnell & Dansereau, 1992) or *external scripts* (Kollar et al., 2007). External scripting involves an approach that aims to scaffold learners and facilitate knowledge acquisition at the level of the groups and the individuals by specifying, sequencing and distributing roles and activities. Different from theatre scripts, external collaboration scripts are to guide and scaffold rather than impose learners' collaborative activities. Different from internal scripts, which are flexible and adaptive to changes in the collaborative situation, external scripts are generally set up prior to collaboration and cannot be adapted to situational demands arising during the collaborative process. One major issue of CSCL research on scripts is therefore to investigate how external scripts can become more flexible for learners to use in different collaborative scenarios and CSCL platforms through specification and formalisation of scripts (see Section 10.3.2).

Another key difference between internal and external scripts is that the latter are represented first by means of cultural artefacts, such as chairs and tables, pen and paper or online discussion boards. External scripts may also be represented in teacher contributions or in a text handed out to the learners (Kollar et al., 2006). Only as a second step are external scripts internally represented by the learners. That is, learners are challenged to make sense of the situation with the help of external scripts, but also to make sense of the external script itself. External scripts thus complement and potentially alter learners' internal scripts. This is especially desirable when the external script represents important strategies within a domain that should ultimately be acquired individually by the learners. To illustrate, goals of science education may include learning how to construct and analyse sound arguments in a domain, how to review literature and critically reflect on hypotheses or how to investigate hypotheses and interpret data. Research on scripts that aimed to facilitate the construction of single arguments and argumentation sequences has shown to facilitate not only the specified activities during the collaborative phase but also the individual acquisition of argumentative knowledge (Stegmann, Weinberger, & Fischer, 2007).

However, not all scripts are to be internalised. Some scripts or script components may regulate effortful functions that are not directly connected to cognitive activities of learning, such as group formation or regulating turn taking within these small groups (e.g. Pfister, 2005). CSCL scripts should be represented in the individual learners' mind to different degrees and time spans for the purpose of modifying the emerging interaction patterns in CSCL environments. These observable interaction patterns can be referred to as another representation of scripts (see Section 10.2.2). They do not result from any single script being executed, but from the combined and reciprocal effect of different learners' internal and external scripts including non-intentional situational affordances.

An important design decision that must be made in the university lecture example is whether the script itself should induce a strategy and to what degree it should be internalised. The university teacher may decide that the students in the course should learn to construct sound arguments based on psychological theories. To this end, learners' messages could be classified as arguments or counterarguments and contain prompts suggesting that learners warrant and qualify their claims. The teacher may also consider what an ideal argumentation sequence in terms of emerging patterns of student interaction is supposed to look like (cf. Stegmann et al., 2007) and what aspects of the argumentative interaction are thought to need support or are already represented within students' internal scripts.

10.2.2 Scripts and Observable Interaction Patterns

The basic rationale of scripted collaboration implies that students acquire knowledge individually by engaging in specific learning activities. Consequently, script design depends essentially on the designer's theoretical model of which specific collaborative learning activities and interaction patterns impinge on individual knowledge acquisition. In one such model, termed *argumentative knowledge construction*, collaborative learners acquire knowledge individually in particular when they construct sound, elaborate and well-interlinked arguments (Weinberger & Fischer, 2004).

Scripts are meant to facilitate individual knowledge construction mainly through supporting these specific activities. However, learners do not necessarily follow a particular external script in full. When especially several scripts exist, learners' actual observable activities and interaction patterns may not resemble any particular script. Both internal and external scripts as well as situational components co-determine the actual interaction patterns observed. Although it has been shown that students basically adhere to external script structures, some variance can be found with respect to the degree to which external scripts regulate collaborative learning activities (Weinberger, Stegmann, Fischer, & Mandl, 2007). Over longer periods of time especially, external scripts may become redundant or even dysfunctional when they are not dynamically adapted to learners' needs throughout the course of the learning process. This dynamic adaptation could be realised by teachers who continuously monitor the collaborative learning activities, by the learners themselves who could choose what script support to select or drop, or by software that could propose scripts to teachers or learners based on automatic analyses of learners' interaction patterns (Dönmez, Rosé, Stegmann, Weinberger, & Fischer, 2005).

There is yet little knowledge about how internal scripts may guide collaborative learners and how learners converge or diverge with respect to how they handle learning tasks together. Typically, students may not make their internal scripts explicit. One may assume that learners quickly converge on a common style (e.g. through primacy effects) and participate according to how motivation and competencies are distributed within the small group of learners (Weinberger, Stegmann, & Fischer, 2007a). As little is known about the ways in which internal scripts of group members interact, there is also little knowledge on how internal and external scripts interact in qualitatively different ways. Thus far, researchers have converged on the notion that external scripting needs to be adapted to learners' internal scripts. The more learners are able to self-regulate their collaborative learning processes, the less elaborated and regulative an external script should be (Cohen, 1994).

With respect to the university lecture example, this leaves us with the question of how to adapt external scripts to learners' internal scripts. After the university lecturer analysed what kinds of internal scripts the students held and how elaborated these internal scripts were, the lecturer could select external scripts that regulate activities that the respective learners would normally not engage in, such as constructing warranted claims. Based on continuous analyses of learners' arguments – possibly supported through automatic discourse analysis software (Dönmez et al., 2005) – the lecturer could decide if and when to gradually fade out the script.

10.2.3 Internalising External Scripts

Early scripting approaches were proposed before computers became ubiquitous learning tools and aimed to facilitate collaborative learning processes by instructing learners to engage in a specific sequence of activities (O'Donnell & Dansereau, 1992). Some of these approaches additionally provided learners with scaffolds, such as sentence starters or prompts that learners were expected to respond to and complete when learning together (King, 1999). Unlike CSCL scripts, learners were taught how to use these early scripts prior to collaborative learning phases, mostly by teacher-guided instruction. Such scripts were represented in paper form or through verbal instructions only. These early approaches often emphasised that the actual goal of scripting collaboration was to help students become self-regulated learners (e.g. King, 2007). At least during the initial stages of the learning process, the facilitation of self-regulated learning therefore entails a certain degree of other-regulation (see Kollar & Fischer, 2006), which in later stages may be gradually reduced or "faded out" (Pea, 2004). From a script perspective, the transition from other- to self-regulation can be conceptualised as a gradual internalisation of scripts – not including those external scripts that are not meant to be internalised (see above). The goal of this internalisation is for learners to become more and more self-guided individuals who can solve problems by relying primarily on their internal resources. Scripts are more effective once internalised, because they are more accessible and a smaller load to working memory capacity than external scripts.

In a study conducted in an inquiry learning context, Kollar and colleagues (2007; see also Kollar, 2006) found that highly structured external CSCL scripts can indeed overlie the internal scripts that learners bring to the collaborative learning situation. However, after the external script was faded out and not available to the learners any more, the learners did not engage in the activities suggested by the external scripts and mainly followed their original internal scripts. Thus, there was no evidence for a strong internalisation of external script components. However, the duration of the learning session was rather short. Internalisation of external scripts may be more likely to be observed over longer periods of time. This, however, is subject to further examination.

Another possibility could be the pace of fading of external scripts. Transition from other- to self-regulation can possibly be realised with a gradual fading of external script components rather than an on–off switch of scripts. CSCL scripts may be more flexibly designed and capable of being faded out in comparison to teacher-instructed scripts (Kobbe et al., 2007). Additionally, regulation of activities may be temporarily shifted from external scripts to co-learners, who could continue to control the engagement in the formerly scripted activities. An empirical study on fading out of computer-supported collaboration scripts in a university context produced promising results by showing that distributing metacognitive functions to co-learners when the script fades out is a fruitful way to facilitate the internalisation of scripts (Wecker & Fischer, 2007).

The university lecturer in our example thus needs to decide how to support the transition from other- to self-regulation and successively fade out the external script components. There are indications that fading out in terms of switching scripts on and off does not necessarily lead to learners' internalisation of the script and continued engagement in activities suggested by the script (Kollar et al., 2007). The lecturer might want to motivate students to continue the scripted activities after the script components are faded out by having the learners mutually control the continued engagement in the specified activities and possibly also by rewarding engagement in these activities.

10.2.4 How Do CSCL Scripts Work?

CSCL scripts are considered an effective means of facilitating specific interaction patterns in computer-supported collaborative learning situations (see Fischer, Kollar Mandl, & Haake, 2007). External scripts are, however, ill defined in terms of how their effects unfold in collaborative learning. Reducing process losses and inducing specific cognitive activities related to individual knowledge acquisition are two major functions of scripts. Introducing computers to classrooms drew attention to the fact that learning and instruction are not only distributed between teachers and students. Cognitive functions may be also distributed among the environment and the tools being used in the learning process. For a first approximation, Kollar and colleagues (2006) therefore proposed viewing CSCL as an instantiation of a "person-plus-surround" system (Perkins, 1993, p. 89). The basic assumption of such a systemic view is that cognition does not (only) happen in the minds of individual learners (the "person-solos"), but that the group as a whole including the artefacts it is using participates in cognition ("person plus surround"). A crucial question in analysing a person-plus-surround system is which component(s) execute metacognitive control such as goal setting or performance monitoring (Perkins, 1993, p. 96, calls this the "executive function" within the person-plus-surround system). The question as to whether students need a script that helps them to perform a particular activity (and thereby takes over the executive function for the system) thus depends heavily on the extent to which the collaborators (or at least one of them) are capable of effectively regulating the group processes themselves.

With respect to inducing activities related to individual knowledge acquisition, scripts should represent the procedural knowledge learners have not yet developed. Still, even when internal and external scripts complement each other, they do not simply combine so that learners are enabled to engage in specific activities, accomplish the learning task and acquire knowledge individually. Internal and external scripts may interact in qualitatively different ways that are yet to be investigated.

From a scaffolding perspective, external scripts induce activities that learners could not engage in without additional support, in the sense of Vygotsky's zone of proximal development (1978). The scaffolds provided to the learners do not make activities necessary to complete the task redundant, but lead learners to engage in the activities relevant for individual knowledge acquisition. From this perspective, it is important to limit scripts to the regulation of specific functions and to include the possibility for learners to take over the activities relevant for individual knowledge construction without further support. If scripts relieve learners of vital collaborative learning activities they might interfere with the social dynamics of the group and even impede learning – a situation known as over-scripting (Dillenbourg, 2002). Scripts might also provide too little help for some students or groups, which could be called under-scripting. Therefore, there is a need to strike an optimal balance between internal and external scripts. One of the major issues in scripting is thus how scripts can facilitate self-regulated learning and which collaborative and cognitive activities the actual human agents in learning and teaching processes in authentic classroom contexts are meant to take over when interpreting an external script and when following script suggestions.

Scripts may also induce specific activities by shaping learners' expectations of what is going to happen in the collaborative phase. Learners expecting to engage in specific activities (e.g. giving explanations) have been found to acquire more knowledge individually than learners who do not (Renkl, 1997). Making the collaborative scenario more transparent through scripts may also alter the motivational configuration of the learning group. For instance, scripts explaining that all group members are required to participate similarly may reduce social loafing and sucker effects (Kerr, 1983; Latané, Williams, & Harkins, 1979). Scripts may also clarify how specific activities may eventually lead to desired outcomes and thus increase learners' motivation (Weinberger & Fischer, 2004).

With respect to reducing process losses, scripts may be designed to take over effortful tasks not directly related to individual knowledge acquisition independent of learners' capabilities. For instance, students may be perfectly able to distribute responsibilities of sub-tasks or develop a schedule of who is doing what at what time. External scripts may, however, take over these organisational tasks, thus allowing learners to spend more time on the actual learning activities (cf. Weinberger, Stegmann, Fischer, & Mandl, 2007). Given that learners generally adhere to script prescriptions, external scripts may also reduce process losses by harmonising different internal scripts. Internal scripts can be considered as culturally shared procedural knowledge, so that learners of one culture may carry similar internal scripts. Collaborative learners from different cultures may thus particularly benefit from following external script prescriptions (Weinberger, Clark, Häkkinen, Tamura, & Fischer, 2007).

With respect to the university lecture example, the script may be designed to first make explicit to the students that they are expected to construct arguments and thus acquire important argumentative knowledge. The script may further contain a task schedule to reduce process losses and facilitate the construction of arguments, as by providing learners with an interface in which messages are titled arguments, counterarguments and syntheses by default (see Stegmann et al., 2007).

10.3 Specification, Formalisation, Design and Deployment of CSCL Scripts

Research on scripts has predominantly been undertaken in the context of European CSCL research, in which the script approach has had an increasing impact over recent years (Fischer, Kollar et al., 2007; Fischer, Weinberger et al., 2007). The CSCL context poses specific difficulties that scripts address, such as learners being at loss of what to do in complex CSCL environments. It has been suggested that unstructured, problem-based CSCL environments are too demanding for learners to actually benefit more from them than from traditional instruction (cf. Kirschner, Sweller, & Clark, 2006). There are indications that collaborative learners surpass individual learners in a complex computer-supported environment only if they are supported by a script (Weinberger et al., 2007b).

The script approach has been at the crossroads of several research and development fields and has attracted special attention, especially in the e-learning community, although sometimes under different terminology. Approaches such as Educational Modelling Languages (EML) in instructional design (Learning Technology Standards Observatory, 2007), workflows in business processes (Vantroys & Peter, 2003) or patterns and visual languages (Botturi & Stubbs, 2008) share many ideas, assumptions and trends with the CSCL script approach (Vignollet, David, Ferraris, Martel, & Lejeune, 2006). Such a confluence heightens the need to take advantage of all previous and current related work, merge these perspectives and converge to a stable and widely accepted solution for all stakeholders (researchers in education, psychology and engineering, together with educational practitioners, or even technology and service providers).

In the university example, the teacher faces the problem of how to put into practice on short notice and without excessive effort all the ideas for a script, taking into account limited time availability and experience in technology-enhanced environments. Thus, the teacher needs to consider the widely adopted Learning Management System (LMS), which has strong support from the university administration, and an EML, which allows expression of the main characteristics of the script. In addition, the script should be easy to describe and design in common language based on established knowledge or innovative approaches towards collaborative learning.

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10.3.1 Life Cycle and Framework for CSCL Scripts

Considerations such as those arising in the university lecture example of specifying and designing scripts drive many current efforts that aim to provide scientific and technological support for different phases of the life cycle of a CSCL script. The integrated framework proposed by the European Research Team CoSSICLE (Computer-Supported Scripting of Interaction in Collaborative Learning Environments; Kobbe et al., 2007) allows understanding and specification of components and mechanisms, that is, the elements and procedures that are necessary for study and research on CSCL scripts. The formalisation of such a framework in computational terms opens the path for the use of computer-based tools for modelling and design of the scripts, while on the other hand it enables the interpretation and execution of such scripts in CSCL environments.

Formal expressions in terms of a computational language disambiguate the specified components and mechanisms. This is a prerequisite for adapting scripts to different learning environments, so as to avoid the proliferation of ad hoc

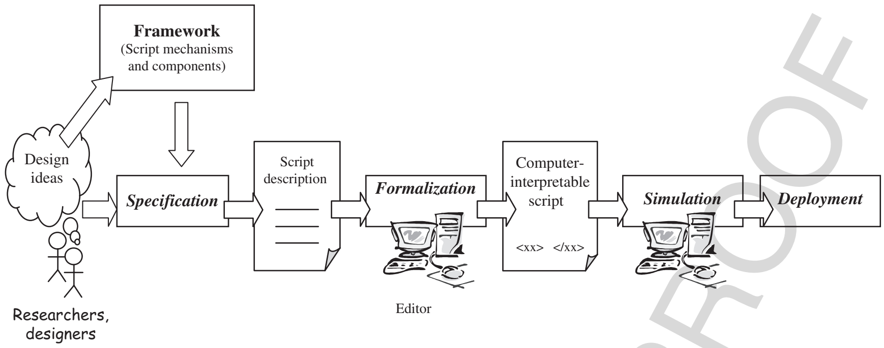

Fig. 10.1 Life cycle of and technology support for CSCL scripts

implementations that are hardwired in a specific system. There is a practical need for a specification and formalisation of scripts to provide teachers and designers of collaborative learning environments with a script toolbox, dynamically adapt scripts during phases of collaborative learning and make scripts transferable from one learning environment to another (see Fig. 10.1).

Teachers may be supported by tools for the conception and delivery of scripts in a general-purpose LMS or a specific CSCL environment. Besides the individual teacher, instructional designers may be more productive in the setup of similar environments, creating a community of teachers who exchange and tailor scripts, data and tools for their classes. It is then possible to expect wider adoption of the CSCL script approach, taking into account the needs of all stakeholders and providing appropriate support.

A stratified approach has been adopted to specify scripts in the CoSSICLE framework, differentiating between schemata and families. While schemata follow some general design principles, script classes are variations of schemata prototypes that are adapted to the specific educational context (i.e. the extrinsic constraints), while complying with the script intrinsic constraints (Dillenbourg & Jermann, 2007). Similar to a pattern-based approach (Hernández-Leo, 2007), this framework builds on existing knowledge that is widely adopted by practitioners while being based on extensive educational research. Its main advantage lies in the flexibility provided to practitioners or educational designers, since they can properly instantiate schemata and families, and facilitates specific interaction patterns that are best suited for specific scenarios.

Different script schemata have been identified (Dillenbourg & Jermann, 2007) such as those that refer to *jigsaw* grouping and re-grouping learners with complementary knowledge (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978), *conflict* grouping learners of contradictory knowledge and roles (e.g. Weinberger et al., 2005) and *reciprocal* facilitating questioning and tutoring activities (King, 2007). Similarly, collaborative learning flow patterns, such as jigsaw, pyramid and think-pair-share, have been detected and included in the pattern-oriented framework that supports similar levels of abstraction and specialisation (Hernández-Leo, Harrer, Dodero Asensio-Pérez, & Burgos, 2007).

In addition to general script schemata and more specialised script classes, the CoSSICLE framework specifies a structural decomposition that conveys a minimal number of elements that cover the needs of a CSCL script. While scripts can be broken down into components, the dynamic and distributed character is defined through mechanisms. With respect to components, roles, for example, are supposed to facilitate specific collaborative learning activities such as question asking, explaining or finding evidence (see King, 2007). On the other hand, participants in the activities may form groups (e.g. expert and super groups in the jigsaw script class) and use computer and network resources, which may be offered as services (e.g. a shared workspace), although individual activities and non-ICT (Information and Communications Technologies) resources are also considered. The dynamic mechanisms that govern CSCL scripts include task distribution among groups and roles, group formation and sequencing of activities. It is noteworthy that many instances of script classes can be described through a small set of components and mechanisms. For example, the specific group formation and rotation of roles are characteristic of the jigsaw script class fostering homogeneous participation in complementary learning activities.

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10.3.2 Languages and Tools for Modelling and Deployment

The selection of a formal language for representing a CSCL script is a crucial aspect, since this modelling language has to be sufficiently expressive for collaborative situations as well as complying with standards. The general approach of EML, such as Instructional Management System – Learning Design (IMS-LD; IMS, 2003), does not take into account all specific characteristics of CSCL, as it has various deficiencies in terms of expressiveness (Caeiro-Rodríguez, Anido-Rifón, & Llamas-Nistal, 2003). However, a de facto standard supported by international organisations motivates independent service providers to create tools that support the whole life cycle and therefore promotes the creation of sustainable technological solutions. Thus, an important dilemma has drawn the attention of researchers and developers in this field: whether to use a proprietary language that allows for richer, more precise and more efficient formalisation of CSCL scripts or to adopt a standard but likely insufficient language such as IMS-LD. While a specialised language for CSCL scripts may coexist, there is a clear trend and need for a solution based on standards that may offer the option for gateways to specific solutions, or paths for future enrichment. There is then the chance for wider adoption by the broad technology-enhanced learning community and it is hoped by educational practitioners, in the direction of solutions based on standards and open source in the general CSCL field.

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The difficulties of this approach are shown in a study related to the widely used WISE science inquiry tool that employs scripting (Berge & Slotta, 2007). Authors found that the SCORM (Sharable Content Object Reference Model) standard

(ADL, 2004) imposed serious limitations on the pedagogical functionality, while use of IMS-LD (IMS, 2003) was feasible and enabled gateways to scripts (projects) developed by third-party designers. Additionally, the adoption of open-source principles and tools is probably one of the major assets that should be taken into account, as exemplified in the Scalable Architecture for Interactive Learning (SAIL) architecture (Slotta & Aleahmad, in press). Thus, the issue of standardisation seems to present the same problems and advantages as in the general discussion of the wider technology-enhanced learning community, namely the trade-off between portability and reuse on the one hand and expressiveness or flexibility on the other. AQ6

Tools and computer-supported environments are final elements that must be provided and considered with respect to technological support for the CSCL script life cycle. For example, an editor is necessary for a researcher, instructional designer or educational practitioner to be able to define the components and mechanisms that formally describe a CSCL script in a computational language. For instance, the Collage editor (Hernández-Leo et al., 2006) allows customisation and generation of hierarchical combinations of collaborative learning flow patterns (script classes), such as jigsaw or pyramid, represented in IMS-LD. An extensive multi-case study (Hernández-Leo, 2007) has shown that educational practitioners are able to successfully formulate their scripts in their specific contexts. An additional element of the CSCL script toolbox points to a simulator which allows designers to run their scripts in a simulated environment and then to reformulate them for a more effective and error-free implementation class environment (Harrer, 2006). Also, players are necessary to interpret the CSCL scripts that have been designed and modelled, such as Coppercore for IMS-LD. Finally, computer architectures are useful to embed CSCL scripts in existing computer-supported learning environments, such as the "remote control approach" (Harrer, Malzahn, & Roth, 2006) or to enable tailoring of CSCL scripts using available tools offered as services, such as Gridcole (Bote-Lorenzo et al., in press). AQ7

In the university lecture example, the teacher may decide to use the jigsaw script schema depending on the respective educational objectives. Then, the basic script components and mechanisms employing the concepts of the previously mentioned CSCL framework can be specified, as, for example, to define an *activity* for a final exchange of arguments between the members of the supergroups that were formed beforehand by the teacher, using the *resource* of an online argumentation forum integrated in a popular LMS. An editor could then be used to formalise the script and produce a machine-interpretable file, eventually in standard EML. Before the deployment of the script, the teacher may detect any eventual problems and reflect on the structure and performance of the script through the use of the available simulator. Finally, an interpreter integrated in a general-purpose LMS may deliver the script in the class, with a possibility of dynamic adaptation, as well as an eventual fading out of the external script.

Notably, teachers may have substantially different requirements than researchers. While researchers may focus on studying the adaptive fading in and out of script components depending on learners' individual needs and deficits, practitioners or administrators are more interested in effectively and efficiently delivering these proposals in the real classroom with certain guarantees for sustainability and scalability. A solution to this dilemma may be of crucial importance and may drive the research and development roadmap in this field.

10.4 Discussion and Outlook

Considering that collaborative learning is partly about adapting and modifying learners' internal scripts, external scripts may provide too little appeal for being internalised. Instead, scripts focus learners on their specific instructions. As a result and depending on the specific script type, learners may, for instance, reply to script prompts rather than to their learning partners or may disregard solving the task in favour of specific social activities or group-formation activities. Apparently, scripts must be adapted to the individual needs of the collaborative learners on multiple dimensions. Otherwise scripts may at best be ignored, but could just as well impede the collaborative learning process (Dillenbourg, 2002; Mäkitalo, Weinberger, Häkkinen, Järvelä, & Fischer, 2005). The approach to this problem suggested here through modelling and design tools that support the deployment and adaptation of scripts seems feasible, but also highly challenging for educational psychology and computer science. First, learners' internal scripts need to be analysed. Second, external scripts need to be adapted accordingly by designers, learners and teachers. Script components could be faded in or out according to the identified learners' needs or their actual effects on the collaborative process. Then again, scripts are entire procedures and may lose their actual instructional meaning when being technically described and broken up into single components.

One of the challenging issues in instructional design of CSCL scripts is to better integrate scripts into wider social planes such as overall classroom activities. The specification and formalisation of scripts can augment the use of scripts in the classroom regardless of the technical learning platform applied. Technical descriptions of scripts realised with specific script modelling tools can not only preserve and convey the underlying educational principles of scripts but also support teachers to realise and orchestrate scripts of different granularities within their classroom. This includes, for instance, the orchestration of individual and collaborative learning phases as well as identification of the role of the teacher within a wider classroom script.

However, there are several limitations in the use of external scripts in authentic classroom contexts that outline steps for future educational research. On the one hand, external scripts do not take into account learners' already existing internal scripts and might capture learners' attention differently than expected. On the other hand, external scripts can predict neither changing needs of individual students nor those of groups. In order to offer the right support at the right time, it is important to track real-time processes so that scripts can fade in or out as necessary. A promising approach is to analyse processes in real time with tools for automatic analysis of natural discourse corpora (Dönmez et al., 2005). Interaction analysis methods and tools (see Chapter 11) should provide sufficient and significant indicators of the real process and its relation to the external scripts, thus enabling flexible script adaptation. This new element of interaction analysis tools, and probably to a lesser extent tools for trails analysis (see Chapter 12), imposes new requirements for interoperability, as already discussed with respect to script design tools. Additionally, longer-term follow-up studies in research on collaboration scripts can identify how fading of scripts can support students in becoming self-regulated learners.

With a few notable exceptions, the social and emotional aspects of self-regulation in collaborative learning scenarios have attracted less attention than its cognitive features (Crook, 2000; see also Chapter 1). However, there are many studies arguing that a sense of community and an open and sensitive atmosphere are necessary preconditions for collaborative learning (Cutler, 1995; De Jong, Kollöffel, Van der Meijden, Kleine Staarman, & Janssen, 2005; Rourke & Anderson, 2002; Rovai, 2000; Wellman, 1999). A strong mood of group togetherness can enhance the flow of information, the availability of support, commitment to group goals and satisfaction with group efforts (Wellman, 1999). De Jong and his colleagues (2005) consider that in order to establish and maintain a secure and collaborative atmosphere, learners should give precise expression not only to ideas and knowledge but also to social and affective propositions. Scripts can be seen as situational and contextual resources in learning environments (Häkkinen & Mäkitalo-Siegl, 2007) that can affect learners' motivation. Therefore, research on learners' goals when using scripts might help us to understand in what ways scripts can also affect student and group goals and whether scripts can contribute to changing these goals in addition to changing internal scripts.

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Chapter-10

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