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Abstract

Collaborative learning is characterized by patterns of relationships between learners. Standard practice usually uses rating scale data to assess collaborative learning and ignores its relational characteristics. Thus, in this paper we use social network analysis (SNA) to answer the following questions: Do progressive school reforms lead to more collaborative learning (as indicated by social network metrics)? And if so, do SNA metrics positively predict students' academic and social competence development? The first question results from the COoperative Open Learning (COOL) concept that is widely used in Austria. The second question is based on cognitive learning theories, which postulate that learning occurs, for instance, when cognitive conflicts arise in a mutual exchange with others and when these are successfully solved, for example, by giving reciprocal explanations. Using data from 504 students in 19 upper secondary commercial school classes in Austria, we performed a series of mean difference tests at the class level and applied multilevel regression models in order to test our hypotheses. The results show that, as hypothesized, COOL classes have more pronounced social network characteristics than traditionally instructed classes. However, contrary to our expectations, only two SNA measures (indegree and reachability) predict students' cognitive outcomes, whereby indegree has a positive and reachability has a negative effect. Class-level SNA measures (such as density of a learning network) did not reveal as significant predictors of neither accounting nor social competence development. With regard to students' social competencies, only students' indegree is weakly but negatively associated with perspective taking skills. This lack of support of our assumptions is discussed in the context of the theory and the COOL concept and against the lack of data on the qualitative nature of the relations between students.

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Keywords

Social network analysis; Collaborative learning; Students' academic achievement in accounting; Pro-social behavior

Effekte sozialer Lernnetzwerke auf Schülerleistungen und das Sozialverhalten im Fach Rechnungswesen

Zusammenfassung

Kooperatives Lernen zeichnet sich u.a. durch Lernbeziehungen zwischen Schülerinnen und Schülern aus. Traditionelle Lehr-Lernforschung verwendet häufig Ratingskalen, um das Ausmaß an kooperativem Lernen zu erfassen und ignoriert dabei den relationalen Charakter kooperativen Lernens. Daher wird im vorliegenden Beitrag die Methode der sozialen Netzwerkanalyse verwendet, um folgende Forschungsfragen zu beantworten: Führen moderne Unterrichtsformen zu vermehrtem kooperativem Lernen (gemessen anhand von Strukturmerkmalen sozialer Lernnetzwerke wie deren Dichte, Hierarchie und Zentralität)? Inwiefern sagen diese Strukturmerkmale den schulischen Lernerfolg sowie die sozialen Kompetenzen von Schülerinnen und Schülern vorher? Die erste Frage ergibt sich aus dem in Österreich weitverbreiteten Unterrichtsmodell des COoperativen Offenen Lernens (COOL), das sich die Förderung des gemeinsamen und kommunikativen Lernens zum Ziel gesetzt hat. Die zweite Frage basiert auf kognitiven Lerntheorien, die postulieren, dass Lernen vor allem dann stattfindet, wenn kognitive Konflikte, die durch den Austausch mit anderen entstehen, erfolgreich gelöst werden und bspw. gegenseitiges Erklären stattfindet. Daten von 504 Schülerinnen und Schülern aus 19 Klassen der berufsbildenden mittleren und höheren Schulen in Österreich wurden mittels einer Reihe von Mittelwertunterschiedstests sowie Mehrebenenregressionen analysiert. Die Ergebnisse zeigen, dass COOL-Klassen, wie angenommen, über stärker ausgeprägte Lernnetzwerkmerkmale als traditionell unterrichtete Klassen verfügen. Allerdings sagen, entgegen den Erwartungen, nur wenige Merkmale (indegree und reachability) die fachlichen Schülerleistungen vorher, wobei indegree einen positiven und reachability einen negativen Effekt aufweist. Auf Klassenebene konnten keine signifikanten Prädiktoren, weder für die fachlichen noch sozialen Schüleroutputs, identifiziert werden. Diese unerwarteten Ergebnisse werden vor dem Hintergrund der Lerntheorien, dem COOL-Konzept und der fehlenden Informationen über die Qualität der Lernbeziehungen diskutiert.

Schlagworte

Soziale Netzwerkanalyse; Kooperatives Lernen; Schülerleistungen im Fach Rechnungswesen; Soziale Kompetenz

1. Introduction

There is no doubt that the ability to collaborate and to work in teams is among the core skills needed today and in future. Employers as well as current educational discussions on competence orientation thus call for (a) students and graduates who possess collaborative learning¹ competencies and (b) educational instructions that foster these competencies. Furthermore, it is not only the professional environment that requires collaboration skills. There is also need for collaboration in an individual's development: Learning theories (like Bandura's (1977) Social Learning Theory) postulate that an individual's cognitive and social development is nurtured by his/her own behavioral or cognitive attributes but also by interaction with significant others or more specific, by his/her social environment. Consequently, collaborative learning is a key method for developing students' academic achievement and pro-social behavior, and can be considered a fundamental part of learning in general (Slavin, 1995; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981). Given the importance of collaborative skills, actors in educational systems, such as policy makers, school leaders and teachers, are required to provide students with learning opportunities that demand and foster collaborative skills. COoperative Open Learning (COOL) – an innovation that was introduced by Neuhauser and Wittwer to upper secondary vocational schools (BMHS) in Austria in 1996 – presents such an opportunity. One central aim of COOL is to promote students' capacities to participate in collaborative learning in order to improve their academic and social competencies. The present paper aims to evaluate the extent to which this goal has been achieved. Therefore, we ask the following question: To what extent does collaborative learning lead to greater academic achievements and more pro-social behavior? In answering this central question, we follow a well-known sociological approach in the context of innovative educational research: We use quantitative social network analysis (SNA) to calculate measures that are linked to students' learning progress and pro-social behavior. More specific, we analyze class and student-level SNA measures such as a class network's density, centrality and transitivity as well as students' in- and outdegree. Whilst the former indicate the connectedness, hierarchy and clustering of students within a class, the latter indicate the popularity and willingness to cooperate of each student. Published studies of collaborative learning have so far assessed *in-class collaboration* by means of self-rated scales, classroom or video observations and/or experimental designs (c.f., Gillies, 2004; Hänze & Berger, 2007; Hijzen, Boekaerts, & Vedder, 2007; Krause, Stark, & Mandl, 2009; Oortwijn, Boekaerts, Vedder, & Strijbos, 2008; Shachar & Fischer, 2004; Tolmie et al., 2010). Social network analysis offers an alternative approach that is better suited to analyzing relational data such as social interactions or social learning (transfer of knowledge) (Carolan, 2013, pp. 11, 15):

1 In the present paper, we use the terms *collaborative learning* and *collaboration* instead of *cooperative learning* and *cooperation* in order to signal that successful collective learning processes require more than simply dividing work.

Whether you are interested in the influence of a school's social structure on an individual actor's achievement, or whether certain opinion leaders are critical to the adoption of a reform initiative, social network analysis operationalizes these patterns of relationships in terms of networks and ties among actors. This perspective differs significantly from the ways in which individual or group behaviour is typically conceptualized and modeled in conventional educational research. Standard practice usually ignores relational information. ... Educational research typically treats learning as an individual outcome, ignoring the messy relational processes through which you form an opinion or an understanding on a topic of interest.

Hence, from a methodological point of view, this paper follows the SNA approach. We build upon the constructivist (Piaget, 1985) and socio-cultural learning theories (Vygotskij, 1986). This work supplements the empirical findings reflected by the meta-analyses by Slavin (1995) and Johnson et al. (1981) as well as recent findings from SNA analyses in educational research (Lorenz & Stubbe, 2014; Vainikainen, Gustavson, Kupiainen, & Marjanen, 2012; Dunkake, 2012; Oswald & Krappmann, 2004). Additionally, we compare our results to findings from COOL evaluation studies (Helm, 2014a; Neubauer, 2010). In order to answer our research questions, we used the following strategy: 609 students from 24 upper secondary vocational school classes with a focus on commercial education were asked to rate each of their classmates as follows: "Indicate how often you work on assignments together with your classmates in accounting." On basis of this data, we calculated several student- and class-level SNA measures (e.g., students in- and outdegree, reachability, density, reciprocity, etc.). Each of them was tested for difference (in their mean) between COOL classes and traditionally instructed classes using *t*-tests and Cohen's *d* effect size at the class-level. Unfolding these differences, it is of central interest, first, if and to what extent these measures are related to students' academic achievement and self-reported pro-social behavior in accounting and, second, if these relations are moderated by the different teaching approaches. In order to answer these questions, we use multilevel regression analysis. However, we have to stick with the first question, since due to the low number of classes, it is not possible to test for moderation effects.

In the next section, we give an overview of central theoretical models that explain how learning occurs in social settings. Additionally, we summarize the state of research regarding collaborative learning in general and COOL in particular. We then develop our hypotheses based on this knowledge. The study design is presented in Section 3. Section 4 briefly states the results, which are discussed against the background of theories on collaborative learning. Limitations of our study and implications for practice are pointed out in the concluding section.

2. Theory and research

2.1 Central theoretical concepts

2.1.1 The COOL concept

Since we examine whether student collaborative learning can be fostered by progressive school models such as COOL, we briefly introduce the concept. Addressing the challenge of coping with student heterogeneity, Georg Neuhauser and Helga Wittwer (two BMHS teachers in Steyr, Upper Austria) implemented new ways of teaching and learning which they called COoperative Open Learning (COOL). COOL is based on the principles of the *Education on the Dalton Plan* (Parkhurst, 1922). These principles are *freedom* (an individual's choice and responsibility for his or her own learning), *collaboration* (working in teams) and *budgeting time* (self-determined planning and organizing learning). Parkhurst's (1922) idea of a modern school describes a way of learning that was strongly influenced by the works of Maria Montessori (e.g., 1916) and John Dewey (e.g., 1916). COOL adopts these educational views, amongst other didactic practices, by fostering collaboration among students (see the quotation below). We thus hypothesized that structural characteristics of social networks are more clearly visible in COOL classes than in traditionally instructed classes. This was assumed in particular for class-level SNA measures such as density and transitivity. Furthermore, we expected effects of COOL on student-level SNA measures (in- and outdegree) as well.

“COOL is teamwork. COOL promotes and demands collaboration. In COOL lessons collaborative methods of working are used in a target manner to foster skills for teamwork and communication” (Wittwer & Neuhauser, 2014, p. 3).

The social principle of the Education on the Dalton Plan does not prescribe tandem and group work but rather removes communication hindering structures students face in traditional school life. Above all, the competitive character of learning in teacher led instructions and learning situations should be relieved and students should have the possibility to collaborate whenever they feel the need for it and beyond the 'borders' of their class. (Hölbling, Wittwer, & Neuhauser, 2015, p. 8)

COOL in accounting. It must be emphasized that it is not the prescription of COOL itself which leads to teamwork in the above mentioned way. Instead, the teachers' pedagogical beliefs make the difference. Seifried (2009, 2012b) could show that accounting teachers with constructivist beliefs more often apply student-centered teaching methods such as group work. It can be assumed – and qualitative teacher interviews support this assumption (Doppler, 2008) – that COOL attracts mainly teachers with constructivist beliefs. What we know for sure is that COOL teachers – in line with the COOL concept – significantly more often use cooper-

ative learning methods (Helm, 2016a; see also Section 2.2). However, as Seifried (2012a) mentions, accounting seems to be a “challenging” (p. 502) subject for constructivist ideas. Just as with mathematics accounting lessons are characterized by high degrees of teacher-led instruction (75 % according to Götzl & Jahn, 2014; see also Seifried, 2012a, 2012b, 2004). According to an online survey with 91 Austrian accounting teachers (Mayer, 2015, pp. 64–65), approx. 24 % of instruction time (i.e., time spent to learn new concepts) is organized either as tandem learning or as group learning that. The share rises to 36 % in exercise phases. Thus, the nature of accounting lessons is rather described by teacher-led instruction and a focus on working out textbook exercises. This should be considered when interpreting the results.

2.1.2 Learning theories

Socio-cognitive learning theories. Since the COOL concept lacks a theoretical basis with regard to collaborative learning, we refer to Krause’s (2007) summary of three central theoretical perspectives that explain collaborative learning: the constructivist perspective (Piaget, 1985), the socio-cultural perspective (Vygotskij, 1986), and the perspective of collective information processing (Hinsz, Tindale, & Vollrath, 1997).

Constructivist perspective. According to Piaget (1985), human beings construct knowledge by interpreting experiences of their physical environment, in particular when cognitive conflicts occur. Throughout this process, assimilation and accommodation play a major role in order to solve cognitive conflicts and retrieve cognitive equilibrium. Assimilation refers to the process by which an individual integrates new experiences and knowledge into existing cognitive schemata. Accommodation, in contrast, refers to developing new schemata and/or extending old ones to explain new information about the environment. With regard to collaborative learning, cognitive dissonances occur when different perspectives clash to an extent that the individual tries to retrieve equilibrium, constructs new knowledge and modifies prior knowledge/cognitive schemata to interpret the world (e.g., Festinger, 1957). Thus, collaborative learning initiates reflection processes that enhance knowledge construction (Krause, 2007, p. 78). However, as Krause pointed out, effects on learning arise most when socio-cognitive conflicts are solved successfully and reciprocal explanations are given within negotiations (Nastasi, Clements, & Battista, 1990; Webb & Farivar, 1999).

Similarly, according to the *socio-cultural perspective* (Vygotskij, 1986), knowledge is co-constructed by group members when trying to find a common understanding of a specific learning content. Again, students are required to externalize (e.g., verbalize) and internalize knowledge.

The *theory of collective information processing* appears to be even more important than the socio-cultural theory. Collective information processing refers to sharing information, ideas and cognitive processes within a group, which in turn

fosters individual and collective learning (e.g., Hinsz et al., 1997). Thus, there are similarities to social network theory.

2.1.3 Social network theory

Social network theory assumes that “one’s relationships with others” (Carolan, 2013, p. 4) play an important role in determining a learner’s educational opportunities and outcomes above and beyond individual characteristics such as sex, age, and socio-economic status. Furthermore, it is assumed that individual characteristics such as educational aspirations shape an individual’s network (e.g., who one knows and spends time with) and vice versa. “Social network analysis, therefore, is not simply an analytical method but a set of theories, models and applications that are expressed in terms of relational concepts and processes” (ibid.). Wasserman and Faust (1994) made the following fundamental theoretical assumptions:

- (1) individuals and their actions are viewed as interdependent; (2) relational ties between individuals are opportunities for transmission of resources; (3) the pattern of relations among individuals – the social structure – is an environment that can either provide opportunities for or constraints on individual action; and (4) social network models conceptualize structure as enduring patterns of relations among actors. (cited in Carolan, 2013, p. 4)

In this study, we attach great importance to the first three assumptions. In accordance with the COOL concept, we view learning as a process that is also collaborative and thus interdependent between classmates. These collaborative learning situations can lead to fruitful moments (Copei, 1930; Klafki, 1958) when cognitive dissonances (see Section 2.1.2) are solved successfully and information and knowledge are transmitted/shared by verbal expressions that are expected to lead to elaboration of higher knowledge (Webb & Farivar, 1999). These relatively specific assumptions are reflected more broadly by social network metrics, such as the *density* of a network or the *indegree* of an individual in a network. We use the term *broadly*, because the quantitative SNA data used in the present study reflects the quality of (individual) social interactions only to a limited extent, that is our SNA question rather asks for the quantity than the quality of the relation to classmates (see the method section below). Our analysis focuses on basic but central dyadic and triadic measures at the class and the student-level, as presented in Tables 1 and 2. The tables list the theoretical arguments for why each measure is relevant to the learning process. Since a coherent theory on the effect of social relations (as indicated by SNA measures) on students learning is missing, it is indeed not clearly determinable why some measures such as centrality or transitivity should be relevant for student outcomes. This indicates that the present study – as one of the first of its kind – is not only of confirmatory but also explorative character. Nevertheless, we think that it is worthwhile to have a look at the impact of

Table 1: Social network measures at the class-level

Measures	Definition (Wasserman & Faust, 1994)	Theoretical argument
Density	“[R]efers to the number of ties in the network reported as a fraction of the total possible number of ties” (Carolan, 2013, p. 102).	Density could be considered a measure for how fast information and knowledge can flow between students within a classroom or learning network.
Centrality	Refers to the degree of hierarchy in a network. “Networks that are centralized ... are ones in which only a small and exclusive set of actors hold positions of power and control” (Carolan, 2013, p. 107).	Centrality provides information on whether exchange of knowledge is initiated by few learners or by many learners.
Average Closeness Centrality	Closeness centrality refers to the sum of the inverse of the farness (i.e., the sum of distances to all other actors), where distance is defined by the length of the shortest paths between all pairs of actors (e.g., Wasserman & Faust, 1994, p. 107). The average is taken at the class-level.	Average closeness centrality provides information on how reachable learners are on average in a network. It also reflects the possibility of loss of information and transfer bias.
Average Reachability	Reachability refers to the ability to go from one actor to another within a network. The average is taken at the class-level (e.g., Wasserman & Faust, 1994, p. 184).	Average reachability provides information on whether the learning network is based on few or on many engaged learners. It indicates “how well resources can move from one part of the network to another” (Carolan, 2013, p. 105).
Reciprocity	Reciprocity is “defined as the degree to which actors in a directed network select one another” (Carolan, 2013, p. 102).	Reciprocity provides information on whether social learning support is unidirectional or bidirectional.
Transitivity	“Reflects the social structure’s tendency toward stability and consistency” (Carolan, 2013, p. 103). Also an indicator of the strength of a network’s tendency to form clusters (small groups) within the network.	An increasing number of transitive triads could reduce cognitive dissonance (Festinger, 1957), since students learn within familiar groups.

several SNA measures since we have reasonable assumptions: As shown in Table 1 we assume that in centralized classes knowledge and information is concentrated at a few students and thus not as easy accessible to other students than in classes with low centrality. The same argument is true for transitivity, meaning that in classes with high clustering information flow is limited. Furthermore, as Festinger (1957) argues, students in classes with high clustering might often learn with familiar partners/groups and thus are less often exposed to cognitive/social conflicts which are important triggers of students’ cognitive and social learning processes.

As the theoretical arguments in the tables show, the SNA measures are closely linked to each other. At least from a theoretical point of view, they are all about how information flows among students and how popular students are when it comes to forming learning tandems. Although we did not have qualitative data available in this study, we assume that the more collaborative learning is indicated by SNA scores, the more learning opportunities (in the sense of social cognitive learning theory as stated above) occur, which thus leads to better academic and social outcomes. Regarding student popularity, we are also aware of an alternative

Table 2: Social network measures at the individual level

Measures	Definition (Jansen, 2006; Stegbauer & Häußling, 2010)	Theoretical argument
Degree (Freeman)	# of relations (ties) of an actor to all other actors	Indicator of connectedness and presence of a student in a class (important for information flow).
Indegree	# of relations (incoming ties) that are directed to an actor (prestige/popularity)	Indicator of how often a student is chosen as learning partner and of his/her popularity in the class.
Outdegree	# of relations (outgoing ties) that are directed from one actor to other actors (social learning engagement)	Indicator of how often students make use of social learning partners (ask for help) and of the openness of the learner.
Closeness	average distance of an actor to all other actors	Degree of reachability of a learner by the others. Indicates how quickly information can be exchanged and how strongly it might be subject to information bias.
Reachability	any set of connections (trace) by which actor A can reach actor B	“Indicates how well resources can move from one part of the network to another” (Carolan, 2013, p. 105).

Note. # = number.

explanation in the sense of reversed causality: Higher (prior) academic achievement leads to higher popularity, since these students are more appreciated by others (Lorenz & Stubbe, 2014; Petillon, 1980; Vainikainen et al., 2012).

2.2 Research on collaborative learning, SNA in education and COOL

Collaborative learning. Two prominent meta-analyses on collaborative learning have been published – one by Slavin (1995) and one by Johnson et al. (1981). Slavin analysed 90 studies and reported:

Seventy-eight per cent of studies of methods using group goals and individual accountability found significantly positive effects, and there were no significantly negative effects. In methods lacking these elements only 37 % of studies found significantly positive effects, and 14 % found significantly negative effects. (Slavin, 1995, p. 42)

Johnson et al. (1981) interpreted their findings similarly:

The voting-method analysis indicates that collaboration promotes higher achievement than competition by 65 to 8 (with 36 showing no differences). The effect size of .78 favouring cooperation indicates that the average person in the cooperation condition performed .75 SD above the average person in competition. (p. 51)

From these and other studies (for a review, see also Lipowsky, 2006), we can derive implications for instructions that are supposed to successfully foster collaborative learning and collaborative skills. These studies could show that collaborative learning is more promising (in terms of improving student academic achievement) when (a) student performance evaluation depends on group performance (positive interdependence), (b) when methods of group work are found that ensure that each individual learner is clearly aware that he or she is supposed to assume responsibility for their group's performance, (c) when the teacher structures and guides student interaction and collaborative learning strategies, (d) when assignments are readily accessible and teachers do not unnecessarily interrupt students working in teams, and (e) when tutoring is demanded that encourages students to verbalize their knowledge and understanding.

SNA studies. Almost 40 years ago, Petillon (1980, pp. 57–58) gave an overview of the state of research in social network analysis. Concerning student academic achievement, he summarized that (a) the association between social appreciation and student performance decreases over years of schooling, (b) repeaters are more unlikely to receive social appreciation, (c) problems with classmates have a negative impact on the willingness to learn, self-confidence, aspiration level, and learning success, and (d) that the perception of supportive teacher behavior is likely to lead to more contacts between students. With regard to pro-social behavior, he summarized that (a) low participation leads to inappropriate social behavior, (b) isolated students possess less empathy, (c) people that are accepted are more often understood, and (d) unpopular students are less likely to solve conflicts in a satisfactory way.

More recently, Carolan (2013) referred to two important US studies. (a) Maroulis and Gomez (2008) found (using ego-network analysis of 85 10th-graders) that a student's location within a network (measured by the density of ties between a student's peers) and the achievement of peers have no average association with student performance after accounting for individual-level characteristics. However, there is a significant interaction effect of network composition and network structure (Carolan, 2013). From this finding, Carolan (2013) concluded that school reform efforts that “focus on ‘connectedness’ (network location) without attending to network composition (embedded resources) are unlikely to achieve the desired result (p. 234).” This could also be true for COOL. (b) Morgan and Todd (2008) tested Coleman's network closure argument: “Students do better when their parents know the parents of their friends, thus creating a dense, redundant network structure” (Carolan, 2013, p. 234). Indeed, it was found that across Catholic schools, parental closure was substantially associated with maths achievement (*ibid.*). However, this did not apply to public schools.

We found only a few studies in the European literature. Lorenz and Stubbe (2014) analysed 208 ninth-graders from eight upper secondary school classes and found that “[h]aving a high number of friends leads to a higher mathematics achievement Being learning partners with many other students that are themselves well connected decreases mathematics achievement” (p. 22). In contrast to

that finding, Vainikainen et al. (2012) found in a sample of 744 Finnish primary school students, that cognitive abilities and pro-social behavior moderately predict student popularity. Nevertheless, popularity is no significant predictor of student academic achievement. One of the few SNA studies using longitudinal data was carried out by Flashman (2012). By means of an actor-based model on the co-evolution of networks and behavior among American students, she found out that, “high-achieving students are more likely to extend ties to other high-achieving students, ... while low-achieving students are more likely to extend ties to other low-achieving students” (p. 61).

Another popular study was done by Dunkake (2012). She examined 200 students from secondary and academic schools. Repeaters and students with pronounced deviant behavior (absenteeism and truanting) were less popular on average, whereas rebellious students were more popular. High performers, in contrast, acted as brokers (i.e., were able to mediate between two other students) more frequently. Oswald and Krappmann (2004) showed, based on a sample of 234 students in Grades 3 and 5, that a student’s position within a network (influence and popularity) is associated with their academic achievement.

COOL evaluation studies. We evaluated the COOL concept over the period from 2011 to 2016. Using a rating scale for collaborative learning (sample item: “In accounting we work on assignments that require reciprocal assistance”) and a sample of 648 9th-graders, we showed that COOL students perceived higher levels of collaborative learning than traditionally instructed students (Cohen’s $d = .43$; Helm, 2016a, p. 252). When relating this measure to student academic achievement in accounting in Grades 9 and 10, a linear growth-curve model revealed a significant standardized negative class-level effect ($b^* = -.39$), even with control for several student characteristics such as their prior knowledge and learning strategies (Helm, 2015). However, this unexpected effect was interpreted as reversed causality, and so collaborative learning was assumed to be implemented particularly in low-performing classes as a remedial tool to promote learning by weaker students. In a different evaluation study ($N = 203$), Neubauer (2010) found that, on average, COOL students did not report more favorable attitudes towards teamwork than students from the control group.

2.3 Research questions and hypotheses

Questions. Does COOL lead to more collaborative learning (as indicated by SNA metrics)? And if so, are SNA scores significant, positive predictors of students’ academic and social competence development?

Hypotheses. In accordance with the COOL concept with its focus on collaborative learning and communication among students, we assume that social network characteristics are more strongly pronounced in COOL classes than in control classes (traditionally instructed classes), except for centrality and transitivity:

Density, average degree: Density as well as class-level averages of students' in- and outdegree are supposed to be higher in COOL classes since COOL students simply more often are forced to learn and work in tandems or small groups.

Centrality: If COOL is applied seriously and if social learning is important to teachers, we assume that teachers will take care that students exchange their learning partners frequently. This should lead to a more balanced social learning network in COOL classes.

Average closeness/reachability: As a logical consequence of the two hypotheses mentioned above COOL should result in higher averaged students' closeness and reachability values since they more often interact with different members of their class than traditionally instructed students do.

Reciprocity/transitivity: We assume that their values are lower on average in COOL classes than in traditionally instructed classes since students are supposed to change their learning partners in open education environments more often than in traditional environments that often provide limited possibilities for cooperative learning (see Götzl & Jahn, 2014).

Furthermore, in accordance with cognitive learning theory, we assume that SNA measures are significant, positive predictors of student academic achievement in the subject accounting at the end of Grade 10 when controlling for students' accounting competence at the end of Grade 9. However, we bear in mind that this hypothesis is somewhat bold, since (a) rating scale measures revealed negative effects and (b) SNA measures do not contain any information about the quality of a learner's collaboration. With regard to pro-social behavior in class at the end of Grade 10, we hypothesize that SNA scores are significant, positive predictors, even with control for general social competence at the end of Grade 9.

Once again, we have to emphasize that due to the small sample, we are not able to test for moderation effects such as: Is students' competence development in accounting in COOL classes more strongly influenced by density than in traditionally instructed classes? These questions appear to be potential future research questions.

3. Methods

3.1 Study design

Our aim was to identify collaborative learning (as reflected in SNA metrics) as a significant predictor of student competence development and student pro-social behavior in accounting. As the literature review above has shown, there have been very few attempts to investigate SNA measures in classroom settings in general and in particular when relating them to student outcomes. Published studies concentrate either on teacher- or school-level investigations (e.g., Penuel, Sussex, Korbak, & Hoadley, 2006), research questions from educational sociology (such as

students' social capital, e.g., Maroulis, & Gomez, 2008), inclusive education (e.g., Henke, Jäntsch, Lambrecht, Bosse, & Spörer, 2015), and/or work with cross-sectional designs (see the literature review above). The present study overcomes these shortcomings by relating SNA measures to longitudinal student competence development data. The data was collected in the subject accounting using online questionnaires and competence tests at the end of Grades 10 and 11, each of which lasted one teaching unit (50 minutes).

3.2 Sample

In order to test the above-mentioned hypotheses, longitudinal data from 24 commercial upper secondary school classes from Grades 10 and 11 was used. However, due to student dropouts and student absenteeism, we had to exclude those classes with more than 20 % SNA data missing from further analyses.² Thus, the sample under investigation was reduced to 19 classes (11 COOL classes and 8 control classes). In four, one, three, and seven of these class(es), four, three, two, and one student(s) was/were respectively missing during the test and thus did not report any SNA data. This missing SNA data was imputed by mirroring the information given by classmates. In other words, we used the transpose of the response matrix: When a particular student did not answer the social network question (see Section 3.3), response data from classmates was used. Since the social network question asks for a reciprocal, symmetric relationship and since there is no single best (multiple) imputation approach recommended in the SNA literature, this imputation approach seemed most appropriate (Borgatti, 2015). In total, 504 students participated in the study. The participants were BMHS students in Austria (75 % girls; M_{age} at the beginning of Grade 9 = 14.5 years, $SD_{\text{age}} = 0.74$). Due to financial and organizational limitations, it was not possible to draw a representative sample from Austrian BMHS classes; instead, classes were selected according to the following two criteria: First, all participating schools had to be certified as official COOL schools by the COOL Impulse Centre (www.cooltrainers.at). This certification guarantees that the COOL concept and, above all, collaborative learning is implemented at a minimum standard defined by the Impulse Centre. Second, for practical reasons, we selected schools with which we already had connections from past teacher training events. In most schools, two COOL classes and two traditional classes took part in the study. Since competence data at the end of Grade 10 was available only for 14 classes, the second set of our hypotheses was tested with a smaller sample. This small number of clusters at the class level limited the number of Level-2 predictors that could be included in multivariate multilevel regressions; however, as Maas and Hox (2005) showed on the basis of simulation studies, multilevel analyses with as few as 10 clusters are meaningful as long as the standard er-

2 As recommended by J. Skvoretz, personal communication, February 10, 2015.

rors for the variances at the upper level are not of interest, which was the case in this study.

3.3 Measures

Social network question. SNA measures (see Tables 1 and 2) in Grade 10 (= t_2) were calculated based on data collected using the following social network question: “Indicate how often you work on assignments in accounting together with your classmate.” The response format was as follows: (a) never or almost never, (b) once or twice a month, (c) once a week, and (d) several times a week. When calculating SNA measures, the response options (a) and (b) were coded 0. Response options (c) and (d) were maintained. Students were given a complete list of their classmates. For each of them they had to answer the social network question separately.

Student competence development in accounting. In order to trace student competence development in accounting, the standardized instrument Test of Basic Bookkeeping Knowledge (*Wissensüberprüfung von Basiskennntnissen der Buchhaltung*, WBB) was used to assess students at the end of each school year in Grades 9 and 10. The WBB was developed by Helm (2016b). The students had to complete 53 items in WBB_{t₁} and 34 items in WBB_{t₂}, which essentially required (a) doing book entries of current business transactions in the trade or the hotel and service industry sector (with and without receipts, WBB_{t₁}), and (b) doing rebooking and additional entries in line with an annual financial statement (WBB_{t₂}). These tasks cover the main content of the curriculum in upper secondary business schools in Austria (BMUKK, 2010). In order to obtain the competency values in accordance with the item response theory, marginal and conditional maximum likelihood estimations were performed using the statistical computing software R with the packages *ltm* (Rizopoulos, 2006) and *eRm* (Mair, Hatzinger, & Maier, 2011). To transform the various test results to a common metric, vertical scaling methods (based on common item design) were applied such that all test values can be interchanged (Kolen & Brennan, 2004). Item Response Theory (IRT) analyses at both test and item level revealed satisfactory reliability (see Helm, 2016b for Rasch model checks at item and test level). Additionally, classical Cronbach’s alpha values are $\alpha = .91$ at t_1 and $\alpha = .80-.87$ for three school-dependent test versions at t_2 . 34 % of the total variance lies at class-level variance (Intraclass Correlation Coefficient, ICC).

Mathematics proficiency. Since mathematics is an auxiliary discipline for students of accounting, they had to complete a 45-minute mathematics assessment at the beginning of Grade 9, which was used as a control variable in the subsequent analyses. Proficiency was measured using 40 items from *Trends in International Mathematics and Science Study* (TIMSS) which reflect the Austrian curricula at Secondary Stage I (Eder, Gaisbauer, & Eder, 2002). The reliability of the test was satisfactory ($\alpha = .79$).

Student pro-social behavior and social competence. Student pro-social behavior was assessed at t_2 using four different scales published by the German Institute for International Educational Research (DIPF; DaQS, n.d.). In total, 18 items assessed the following four constructs: social engagement (e.g., “I helped classmates to navigate the lessons.”), social support of others (e.g., “I tried to help classmates with assignments I had already completed.”), perspective adoption (e.g., “In the event of a difference of opinion, I try to see the problem from all parties’ perspectives before I make a decision.”), and conflict-solving skills (e.g., “I accept justified arguments of others even if they conflict with my arguments.”). All items had a response format from 1 (= *I totally disagree*) to 5 (= *I totally agree*). The reliability of the subscales was satisfactory ($\alpha = .74-.84$). The interpersonal competence questionnaire (ICQ; Riemann & Allgöwer, 1993) was used as a control variable at t_2 to assess general social competencies. The ICQ captured five subscales (initiating relationships, disclosing personal information, asserting displeasure with others, providing emotional support and advice, and managing interpersonal conflict) using 40 items. In the present study, an overall index was built by averaging over all five subscales. The reliability was satisfactory ($\alpha = .92$).

3.4 Statistical analyses

For the purpose of answering the research questions, we first calculated SNA measures (explained in Tables 1 and 2) using the R package *sna* (Butts, 2010). Next, we calculated *t*-test statistics and Cohen’s *d* at the class-level to test differences between COOL and traditional classes in terms of statistical and practical relevance. We then transferred individual- and class-level SNA measures to permutation correlation tests and to multilevel regression analyses in order to relate SNA measures to students’ outcomes and to predict students’ outcomes while controlling for prior performance. These analyses were done in Mplus (Muthén & Muthén, 1998–2014). Since some of the student-level SNA measures are correlated with each other ($r_{\text{Outdegree_Closeness}} = .74$), we tested for multicollinearity. The variance inflation factor (VIF) ranges from 1.052 to 2.407 among the predictor variables, with one exception (4.368), indicating that there is no multicollinearity issue since these values are clearly below the rule of thumb of 10. Since our SNA data represents dependent data we did permutation correlation tests. These tests fulfil the statistical requirements for inference testing on dependent data (i.e., SNA measures at the student-level are not independent of each other and thus violate the basic independence assumption underlying traditional inference statistics; see, e.g., Carolan, 2013), whereas in our multilevel regression models, this is not the case. Thus, care must be taken when interpreting standard errors reported at Level 1 in the multilevel models. Due to the small number of observed classes and the sensitivity of significance testing to sample size we report and interpret effects at the *p* value level of $\leq .10$.

4. Results

Table 3 shows results from *t*-tests and Cohen's *d* calculation for each SNA measure at the class level. As hypothesized, COOL classes have denser learning networks (density and average degree) and are more centralized, and COOL students are on average more reachable. Both *t*-test results and Cohen's *d* show that these differences are statistically and practically relevant and in favor of COOL classes. In contrast, with regard to closeness, reciprocity and transitivity, the average differences between the two instructional designs are either insignificant or point in the opposite direction.

Table 3: Mean comparison of basic SNA measures in COOL and traditional classes

SNA measure	trad.	COOL	<i>t</i> value	<i>df</i>	<i>p</i> value	Cohen's <i>d</i>
Density	0.13	0.17	-1.82	14.48	0.04	0.76
Av. freeman degree	22.42	28.10	-2.06	15.45	0.03	0.87
Av. indegree/out-degree	11.21	14.05	-2.06	15.45	0.03	0.87
Centrality	0.65	1.06	-1.69	16.56	0.05	0.73
Average closeness	0.15	0.17	-0.34	16.97	0.63	0.15
Reciprocity	0.87	0.85	1.57	14.89	0.07	-0.73
Av. reachability	0.70	0.87	-2.05	9.10	0.96	1.06
Transitivity	0.36	0.40	-0.86	17.00	0.80	0.38

Notes. trad. = traditional instruction. *df* = degrees of freedom. Av. = average.

With regard to our second set of hypotheses, results from permutation correlation tests are reported in Table 4. Student competence at the end of Grade 10 is, only at the class level, negatively related to density and transitivity of the class study network, though the error probability of that estimate is high ($p = .074/.083$). At the student level, there are no SNA measures related to students' academic achievement. With regard to student social behavior, the results show that student outdegree, closeness and reachability are positively related to student social engagement and support of others. At class level, no SNA measures revealed significantly associated with students pro-social behavior.

Linking SNA measures to student outcomes and controlling for prior attainment led to several multilevel regression models, as presented in Tables 5 to 7. Due to the low number of clusters (school classes) at Level 2, a series of multilevel models was applied in order to test each Level-2 SNA measure separately, first, controlling for prior class average math ability and second, controlling for prior class average accounting ability. In all models (M1 to M12), only student indegree was a significant positive student-level predictor for student academic achieve-

Table 4: Results from a permutation correlation test between SNA measures and student performance as well as student social behavior in class

SNA	WBB 2		Social engagement		Support others		Perspective taking		Conflict-solving skills	
	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*
Indegree										
Outdegree			0.114	0.063	0.196	0.000				
Closeness			0.116	0.045	0.181	0.002				
Reachability					0.135	0.019				
SNA	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*	Corr	ρ^*
Density	-0.433	0.074								
Centrality										
Reciprocity										
Transitivity	-0.414	0.083								

Notes. $\rho^* = \Pr(\rho \geq \text{obs})$. Correlations with a tendency towards statistical significance ($p \leq .10$) are displayed too.

ment in accounting ($b^* = .084$). Student reachability negatively predicts accounting competence ($b^* = -.149$). At the class-level, prior cognitive abilities (mathematics at the beginning of Grade 9 and accounting competence at the end of Grade 9) are clearly the strongest predictors of student performance in accounting at the end of Grade 10. However, when controlling for students' prior attainment in accounting, the average reachability of a class is negatively associated with student accounting performance one year later ($b^* = -.316$), though the error probability of that estimate is larger .05 ($p = .077$).

With regard to students' pro-social behavior in class, Tables 6 and 7 show that at the student-level only students' general social competence (measured using the ICQ) is a significant predictor for all four subscales of the pro-social behavior scale. In the case of the *perspective taking* subscale, student indegree is also a significant but negative predictor. Furthermore, the reachability of students is negatively associated with *conflict-solving skills*. At class level, no SNA measures predicted students' pro-social behavior. This is partly due to the low between class variance of the four pro-social behavior subscales ($ICC < .10$). However, average students' interpersonal competence (ICQ) of a class is strongly related to *students' social engagement* and *support of others*.

Table 5: Multilevel regression analysis models predicting student academic achievement at the end of Grade 10.

Level 1 (group mean centering)		Estimate	SE	Estimate	SE
M1–M12:	Accounting ability (Grade 9)	.436	.047		
	Maths ability (start Grade 9)	n.s.	n.s.		
	Indegree	.084	.036		
	Outdegree	n.s.	n.s.		
	Closeness	n.s.	n.s.		
	Reachability	-.149	.072		
Level 2 (grand mean centering)					
M1/7	Density	n.s.	n.s.	n.s.	n.s.
M2/8	Centrality	n.s.	n.s.	n.s.	n.s.
M3/9	Reciprocity	n.s.	n.s.	n.s.	n.s.
M4/10	Transitivity	n.s.	n.s.	n.s.	n.s.
M5/11	Av. Closeness	n.s.	n.s.	n.s.	n.s.
M6/12	Av. Reachability	n.s.	n.s.	-.316	.178
M1–M6:	Maths ability (start Grade 9)	.693–.780	.121–.155		
M7–M12:	Accounting ability (Grade 9)			.847–.922	.073–.090

Notes. Fixed standardized effects are reported. n.s. = not statistically significant. SE = standard error.

Table 6: Multilevel analysis predicting students' social engagement and social support of others at the end of Grade 10

	Social engagement		Social support of others	
Level 1 (group mean centering)	Estimate	SE	Estimate	SE
ICQ (Grade 10)	.130	.073	.141	.066
Level 2 (grand mean centering)				
ICQ (class mean, Grade 10)	.884	.225	.883	.429

Notes. Fixed standardized effects are reported. SE = standard error.

Table 7: Multilevel analysis predicting students' perspective adoption and conflict-solving skills at the end of Grade 10

	Perspective taking		Conflict-solving skills	
Level 1 (group mean centering)	Estimate	SE	Estimate	SE
Indegree	-.082	.038		
Reachability			-.0128	.067
ICQ (Grade 10)	.245	.048	.223	.055
Level 2 (grand mean centering)				
All class-level predictors	n.s.	n.s.	n.s.	n.s.

Notes. Fixed standardized effects are reported. n.s. = not statistically significant. SE = standard error.

5. Discussion

Our aim was twofold: On the one hand, to evaluate to what extent collaborative learning (as indicated by SNA metrics) could be promoted by progressive school models such as the COOL concept, and, on the other hand, to determine whether collaborative learning is a significant predictor of student competence development and student pro-social behavior in accounting using relational data and measures from social network analysis.

5.1 Summary

The first goal is reflected by the hypothesis *COOL classes have higher SNA scores*, which was clearly confirmed by the data collected and the analyses conducted. Both *t*-tests and Cohen's *d* effect size support the assumption that the COOL concept is a viable approach to fostering collaborative learning, although COOL is not related to the average closeness and transitivity of a class' learning network. Furthermore – and contrary to our expectations – reciprocity even seems to be negatively associated with the COOL approach. One explanation is that collaborative learning in COOL classes is more often characterized by changing learning partners. In contrast, traditionally instructed classes provide learning tandems that are more stable and thus report reciprocated relations and closure among students more often. Another unexpected finding is that centrality is higher in COOL classes than in the control group. One reason might be that in open education centrality is more likely to evolve faster since students can choose their learning partners freely whereas in teacher-centered instruction students hardly ever receive that choice. Nevertheless, COOL teachers obviously succeed in removing structures that hinder communication in everyday school life – at least in the subject accounting. Working assignments that demand collaboration do indeed seem to be an appropriate way of increasing collaborative learning. These findings are in line with the findings of Helm (2016a), who used rating scales. So far, we do not yet know anything about the quality of the collaboration between students, since we do not have qualitative data on how they realize collaboration. Given this lack, we asked whether more intense collaboration is associated with better student outcomes, assuming that collaboration supports learning per se.

However, this assumption seems to lack empirical support since our second set of hypotheses was not confirmed by the data. At the student-level and with control for prior attainment, indegree (i.e., a student's popularity) significantly predicted students' learning progress in accounting. Though this finding might be limited to our sample (due to non-significant permutation correlations), it is not surprising, as we know from previous studies (Lorenz & Stubbe, 2014; Oswald & Krappmann, 2004; Vainikainen et al., 2012) that popularity is related to academic achievement. In contrast, with controls for prior math and accounting abilities, students with

higher outdegree and higher closeness (both indicators of lower information bias and better access to information) do not progress more. Thus, it is even more surprising that a higher students' reachability is related to lower competence gain. All in all, it seems that the location of a student within a learning network and his or her social learning engagement do not affect the learning outcomes very much. Even class-level SNA measures are not related to students' academic growth in accounting. Though according to permutation correlation tests density and transitivity are negatively correlated with students' accounting performance, this association vanishes when controlling for students' prior attainment. Thus it seems that in low-performing classes, learning networks are denser, however, the density itself has no effect on students' progress in accounting.

These findings from social network analyses are not in line with those from rating scale analyses reported above (Helm, 2016a). These different findings are very likely due to the different instruments used to assess cooperative learning. While in the present study SNA data on *who learns with whom* was collected, the former study used Likert-scaled items to assess how often group work activities are applied during accounting lessons. In fact, they measure different things and cannot be compared.

Nevertheless, again we must point out that these preliminary analyses and findings on student collaboration are relatively limited, since we know hardly anything about the quality of student collaboration within learning networks.

Regarding the prediction of students' pro-social behavior in class, only a student's indegree at Level 1 proved to be a significant but negative and weak predictor of students' perspective taking ability. This finding and the lack of effects of all other SNA measures are in clear opposition to what theory predicts. For instance, we expected that students with higher outdegrees and reachability would have more opportunities to learn to adopt other perspectives and to overcome social conflicts. However, this is only true in bivariate analyses as the permutation correlation tests show. When controlling for interpersonal competence, these results diminish. With regard to students' outdegree, one should be aware that this measure represents a subjective indicator for the student's position in a social learning network. It is plausible to assume that unpopular children show a strong outdegree which is not answered by others (e.g., Festl & Quandt, 2013, p. 115). In addition, we assumed that classes with higher density provide more of these social learning opportunities and thus will foster students' social learning. It seems that this is not the case. However, bear in mind that we do not have qualitative data on how students use these learning opportunities to develop their social behavior. It is conceivable that some classes/some students solve social conflicts in a way that allows them to learn and improve their social behavior. Other classes/other students may not be able to solve these situations in a fruitful way. They may even lead to a decrease in social competences, particularly when conflicts are solved inappropriately (e.g., at the expense of others).

5.2 Strength and limitations of the present study

The major strength of the present study is that it models collaborative learning by using data that reflects the relational character of learning networks rather than by relying on self-reported scales, as is usually the case. Another strength is that this relational data is related to longitudinal (developmental) cognitive and non-cognitive (social competence) data instead of relying on a cross-sectional design. Although the present analysis is a field study, its generalizability is limited because we do not know to what extent the selected sample is representative of students and classes from vocational schools from all over Austria. Moreover, the sample shows a high proportion of girls. Even though this is a characteristic of the Austrian commercial education at Secondary Stage II (see Statistik Austria, 2015, p. 31: 73.4 % female) social relations among students might also be influenced by gender, for instance clustering due to homophily with regard to gender. Indeed, it is very likely that homophily drives group composition for learning especially in COOL classes. In other studies (e.g., Helm, 2014b), COOL students report higher freedom of choice: In line with the COOL principles, over 70 % of COOL students report that they are allowed to choose their learning partners themselves always or often. This indicates further need for longitudinal research about selection processes in open learning vs. traditional learning environments. With regard to the sample, another limitation became clear throughout this study: The analysis of moderation effects due to the different teaching approaches was not possible since the number of classes for both, the COOL and the traditional approach, was too small for multilevel multiple group comparisons.

The major drawback of the present study is the lack of qualitative data that would allow us to identify learning networks and social relations that are assumed to enhance learning (e.g., that force students to verbalize their understanding of new topics). As Wasserman and Faust (1994) pointed out, a pattern of social relations can either enable or constrain individuals' action and learning. Moreover, we did not take network composition (embedded resources) and its interactions with network structure into consideration, as done by Maroulis and Gomez (2008). It might be that only dense learning networks with rich knowledge resources reveal positive effects. Furthermore, we ignored the relation and the interaction effects between student socio-metric position and the sociodemographic and personal characteristics. One could question if student outputs (as focused here) might not only depend on students' social integration (indegree) and access to information (betweenness centrality) but also on students' cognitive ability and motivational willingness to make (efficient) use of available contextual resources, like seeking help from others or discuss and elaborate on concepts. Thus, psychological and sociodemographic characteristics should be considered too when analyzing the role of social network positions (Dunkake, 2012). Several issues emerge here on which further research should continue to focus. Thus, our current conclusions are formulated very broadly for teaching practice in general.

Beyond the lack of qualitative data, we must critically emphasize the use of self-rating scales for assessing social competence. It would be interesting for future research to assess students' pro-social behavior using classmate-ratings.

5.3 Implications for teaching practice

The results of the present study show that collaborative learning might be increased quite fast by using progressive ways of teaching (which, of course, implies more effort and work), but teachers should be aware that collaborative learning does not run itself, as the highly promising results from meta-analyses stated above might suggest. The present study reveals, in addition to positive effects, several negative associations between SNA measures and learning processes. Thus, teachers must plan and arrange collaborative learning environments carefully. The literature reviewed above gives several hints and principles that maximize the likelihood of successful collaborative learning. According to these, teachers must ensure (a) positive interdependence, (b) students' responsibility for their group's performance, (c) structures and guidance for student interaction and collaborative learning strategies, (d) readily accessible assignments and smooth teamwork and (e) tutoring that forces students to verbalize their knowledge and understanding.

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