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Disseminating educational innovations in health care practice: Training versus social networks

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ABSTRACT

Improvements and innovation in health service organization and delivery have become more and more important due to the gap between knowledge and practice, rising costs, medical errors, and the organization of health care systems. Since training and education is widely used to convey and distribute innovative initiatives, we examined the effect that following an intensive Teach-the-Teacher training had on the dissemination of a new structured competency-based feedback technique of assessing clinical competencies among medical specialists in the Netherlands. We compared this with the effect of the structure of the social network of medical specialists, specifically the network tie strength (strong ties versus weak ties).

We measured dissemination of the feedback technique by using a questionnaire filled in by Obstetrics & Gynecology and Pediatrics residents ($n = 63$). Data on network tie strength was gathered with a structured questionnaire given to medical specialists ($n = 81$). Social network analysis was used to compose the required network coefficients.

We found a strong effect for network tie strength and no effect for the Teach-the-Teacher training course on the dissemination of the new structured feedback technique. This paper shows the potential that social networks have for disseminating innovations in health service delivery and organization. Further research is needed into the role and structure of social networks on the diffusion of innovations between departments and the various types of innovations involved.

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Introduction

Innovation in health service delivery and organization has become a central issue. The reasons for it becoming so range from failure to use the available scientific knowledge (Richardson, 2001), to rapidly rising costs due to changing demographics and medical technology (Hartman, Martin, McDonnell, & Catlin, 2009), medical errors (Berwick, 2003), and the very organization of the health care systems themselves (Kuttner, 2008). Many innovation projects often fail to meet expectations. There are six forces which seem to drive or kill innovations: players (friends and foes), funding, policy, technology, customers, and accountability (Herzlinger, 2006).

Many of the innovations in health care organizations are implemented by following a training course or other kind of education. The expenditure incurred for training and education is considerable. In the USA an average health care organization's (500–999 FTE) annual training expenditure exceeds $150,000 (Controller's Report, 2006). The average annual direct training expenditure per FTE in health care in the USA is $862, which constitutes on average 12% of profit (Corporate Training & Development Advisor, 2008).

As a result, the question then arises as to how effective training and education actually are in distributing and transferring novel ideas, new health concepts, and technologies. Are there more

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effective, less time-consuming and therefore cheaper ways to disseminate knowledge in health care practice?

In this paper we will examine the effects of an intensive Teach-the-Teacher training course versus the effect that the structure of the social network has on the adoptive behavior of medical health care professionals. More specifically, we will look at the effect of network tie strength on the dissemination of a new structured feedback technique among medical specialists.

Theory and hypotheses development

Training and education: the effect of Teach-the-Teacher training

A large amount of literature is available on the effectiveness of training and education in general. This has been summarized in a meta-analysis showing a medium to large effect for training and education when using a composite measure of Kirkpatrick's evaluation criteria (i.e., reaction, learning, behavior, and results) (Arthur, Bennett, Edens, & Bell, 2003; Kirkpatrick & Kirkpatrick, 2006). Another review showed, that training and education lead to important benefits for individuals and teams, organizations and society (Aguinis & Kraiger, 2009).

Meyers and Sivakumar (1999) identified training and education as key factors influencing organizational innovation and implementation. Training can create a positive climate and attitude by increasing familiarity and technical competence. Training leads to more specialization which, in turn, can lead to a broader knowledge base, stimulate the exchange of ideas and foster innovation. Training can also lead to more professionalism, more boundary-spanning activities and increased openness to new methods and ways (Meyers & Sivakumar, 1999).

Steinert et al. (2006) conducted a review of the effectiveness of teaching faculty development initiatives in medical education. They defined faculty development as those planned programs which prepare institutions and faculty members for their academic roles, including teaching, research, administration, writing, and career management. Steinert et al. limited their review to faculty members' teaching abilities in medicine. Faculty development activities appeared to be highly valued by the participants, who also reported changes in learning and behavior. However, student/resident evaluations did not always reflect the behavioral changes that the participants perceived, and changes in organizational practice and student learning have not been investigated very frequently since (Steinert et al., 2006).

Recently a long-term controlled study showed that Teach-the-Teacher courses, aimed at improving the didactic skills or teaching abilities of doctors, significantly increased doctors' didactic knowledge and teaching behavior, and led to improvements in the clinical learning climate (Rubak, Mortensen, Ringsted, & Malling, 2008).

Thus, while the beneficial effects of training and education in organizations *per se* have been well documented, the effects of Teach-the-Teacher training in health care organizations are less clear.

To examine the effect of Teach-the-Teacher training on adoptive behavior, we hypothesize that:

Hypothesis 1
Teach-the-Teacher training will have a positive effect on the adoptive behavior of medical health care professionals.

Social networks and the effect of strong and weak ties

Social networks are assumed to play an important role in the diffusion and dissemination of innovations. Social networks influence diffusion by (1) functioning as channels for communication, social construction and negotiation of the innovation, (2) by increasing the observability of the innovation and, therefore, (3) by reducing the perceived risk by eliminating novelty or uncertainty for potential adopters of the outcome of the innovation (Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004; Larsen & Ballal, 2005; Rogers, 2003). Social relationships and social networks are critical for the sustainability of health care innovation (Sibthorpe, Glasgow, & Wells, 2005).

Diffusion of innovations through social networks has been studied from a number of perspectives in a variety of fields and disciplines (Greenhalgh et al., 2004; Wejnert, 2002), for example, in the diffusion of family planning (Boulay, Storey, & Sood, 2002) and health campaigns (Valente & Fosados, 2006). Despite the importance that interpersonal influence through social networks has on the diffusion of innovations, some sectors and organizations and some types of innovation have been ignored in prior research. In a comprehensive literature review on the diffusion of innovations in health service organizations, Greenhalgh et al. (2004) concluded that, although the conceptual framework of social networks had been extensively applied to the adoption of particular health technologies, the empirical literature on the social networks of health professionals as related to the diffusion of innovations in service delivery and organization (as opposed to health technologies) was extremely sparse.

A social network can be defined as a finite set of actors and the relationships defined between them (Wasserman & Faust, 1994). In the application of Social Network Analysis (SNA), generally speaking actors can be interpreted as discrete individuals, or groups of individuals, business units, entire organizations or even as countries. The same holds for relationships or relational ties. In the case of SNA, these can be just about everything, for example, an exchange of products, trust, power, friendship or information. In the application of SNA to the diffusion of innovation, the actors are individuals, groups and business units (intra-organizational) or organizations (inter-organizational), and the relational ties consist of the exchange of information, communication, friendship or trust. The configuration of the actors and the relational ties they have with each other – or the structure of the social network itself – can influence the diffusion of innovation in several ways. Two perspectives emerge in the literature: the "strength of strong relational ties" and the "strength of weak relational ties" (Tenkasi & Chesmore, 2003).

The first perspective is mainly based on the notion of homophily. Homophily is defined by Rogers (2003) as "the extent to which two or more individuals who interact are similar in certain attributes, education, social status and the like." Between people who are more homophilous, contagion effects occur: An individual adapts his behavior, attitude and beliefs to those of others, which then enhances the diffusion of innovations. Homophily and communication reinforce each other: The more communication there is between members – or the stronger the tie between the actors – the more likely they are to become homophilous (Rogers, 2003). Strong relational ties also provide more opportunities for instruction and feedback, which can in turn enhance successful adoption (Tenkasi & Chesmore, 2003). Interpersonal contacts and communication increase the observability of the innovation and therefore reduce the perceived risk by eliminating novelty or uncertainty for the potential adopters of the outcome of the innovation (Greenhalgh et al., 2004; Rogers, 2003). More frequent communication decreases potential risk and results in higher diffusion and adoption. Social networks with a larger number of strong ties – or dense networks – create optimal conditions for the exchange of the complex information necessary for innovation in complex organizations (Hansen, 2002) and for the origin of high quality ideas (Björk & Magnusson, 2009).

Weak relational ties also have their advantages. External (weak) ties (or structural holes) allow new innovations to be identified and captured from outside the network. Individuals whose networks span structural holes have early access to diverse information, which provides them with a competitive advantage by seeing good ideas and having early access to innovations. Weak ties are often more important in spreading information or resources because they tend to serve as bridges between otherwise disconnected groups and to facilitate access to different contacts and resources (Burt, 2004; Granovetter, 2005).

West and Barron (2005) studied the social networks of clinical directors in medicine and directors in nursing. The former have significantly denser, more cohesive and more horizontal social networks than the latter and both groups tend to discuss important professional matters with others who are similar in terms of profession, gender, age, and seniority, with clinical directors being more extreme in this regard (West & Barron, 2005). Coleman, Katz, and Menzel (1966) studied the diffusion of a prescription drug Gammanym among 125 physicians in four American Midwestern communities. They found the more links and contacts a physician was involved in, or the stronger the ties a physician had, the more likely he or she was to be an early user of Gammanym. Physicians who were more isolated in the network adopted the drug considerably later. The impact upon the integrated physicians was quick and strong, while the impact upon isolated physicians was slower and weaker, though not absent (Coleman et al., 1966). A recent study on prescribing behavior of General Practitioners (GPs) in Italy found no significant relationship between the strength of GPs' ties (as measured by degree centrality) and their performance (meeting a drug expenditure target) (Fattore, Frosini, Salvatore, & Tozzi, 2009).

No study looked into the combined effect of the strength of strong and weak ties on the adoptive behavior of health care professionals.

For the successful diffusion of innovations, both strong and weak relational ties seem to be necessary. Weak ties are necessary to acquire new ideas and strong ties are necessary for subsequent implementation (Burt, 2004; Reagans & McEvily, 2003).

To examine the effect of strong and weak ties in the medical setting, we hypothesize that:

Hypothesis 2
Medical health care professionals who have strong ties will be more likely to show adoptive behavior.

Hypothesis 3
Medical health care professionals who have weak ties will be more likely to show adoptive behavior.

Hypothesis 4
Medical health care professionals who have both strong and weak ties will be more likely to show adoptive behavior than medical health care professionals who only have either strong or weak ties.

Methods

Background: innovations in postgraduate medical training in the Netherlands

We used data from the innovations in the postgraduate medical specialist training programs in the Netherlands to test our hypotheses. The Netherlands has 33 postgraduate training programs (for example, Surgery and Pediatrics) following medical school and they take place in eight university and about 60 non-university teaching hospitals. Postgraduate training has consisted mainly of "learning on the job." Residents (medical specialists in training) work under the supervision of a team of qualified medical specialists and learn by reflection on experiences. In this program, neither the method nor the frequency of feedback is structured. Evaluation of the progress of residents is, therefore, rather informal.

In 2004, the Royal Dutch Medical Association (KNMG-CCMS) introduced competency-based education in postgraduate training throughout the Netherlands (Scheele et al., 2008). Traditionally residents had been trained according to a pre-defined input (for example, number of operations, number of months in clinical consultation and practice). Assessment was limited to checking whether these numbers were met. In competency-based education, medical specialists are now trained according to certain competencies: medical expert, collaborator, communicator, professional, health advocate, management and scholar (Frank & Danoff, 2007). The periodic assessment which takes place now focuses (using a variety of methods) on knowledge and skills possession relevant to clinical practice.

Key innovations introduced by the Royal Dutch Medical Association were the use of the Mini Clinical Evaluation Exercise (Mini-CEX) and the use of structured competency-based feedback (Royal Dutch Medical Association (Centraal College Medisch Specialisten), 2004). The Mini-CEX is a method of assessing competencies in real-life clinical practice. It consists of a short observation of a resident demonstrating clinical skills, and is carried out by a qualified medical specialist using a pre-defined scoring format, followed by a structured feedback conversation (Norcini, Blank, Duffy, & Fortna, 2003). The method and frequency of the structured feedback are outlined. As a result, medical specialists are expected to adopt a novel structured feedback format. The Mini-CEX and structured feedback were to be adopted and implemented by all teams of medical specialists that train residents. Our study focuses on the dissemination process of structured feedback within teams of medical specialists. The innovation could originate either from outside or from within the group. Ethical approval was deemed unnecessary for this study.

Sample

The medical specialties of Obstetrics & Gynecology (O&G) and Pediatrics were the first in the Netherlands to implement the innovations in their curriculum (In-VIVO Project, 2006). Data were gathered in 2007 from four O&G departments and five Pediatrics departments in the Netherlands. Two of the authors were members of the implementation team for the O&G and Pediatrics curriculum in the region, which allowed access to the research field. The total sample consisted of 105 gynecologists and pediatricians and 86 residents in O&G and Pediatrics.

Data gathering

The medical specialists and residents received both a structured and validated questionnaire (see below). The questionnaire for the medical specialists included questions about the following topics:

- independent variables	Whether a Teach-the-Teacher training course was followed Evaluation of communicational tie strength with fellow medical specialists
- control variables	Gender, age, attitude, hours, and length of employment

The residents were asked to assess how capable the medical specialists were in giving structured feedback (dependent variable).

Dependent variable

Adoptive behavior: structured feedback

We used the "structured feedback" given by medical specialists to residents as the dependent variable. Structured feedback is based on "Pendleton's rules" (Pendleton, Schofield, Tate, & Havelock, 2003) and consists of the following components:

(1) the feedback is structured
(2) the medical specialist gives the resident the opportunity to give his/her opinion
(3) the medical specialist provides positive points
(4) the medical specialist provides specific points for improvement
(5) the medical specialist provides the feedback in a "safe" way.

Every medical specialist was rated by at least two residents on the above components on a five-point Likert scale ranging from "totally disagree" to "totally agree."

Independent variables

Teach-the-Teacher training

Many medical specialists in our sample had followed a Teach-the-Teacher course which was aimed at improving the didactic skills or teaching abilities of the participants. The training consisted of three sequential two-day courses. Registration for the second and third courses was dependent upon successful completion of the first course. The introductory course comprised training in structured feedback, training in the Mini-CEX, and the basics of adult learning. The second course comprised training in daily educational practice, which includes organizing day-to-day training for residents and adapting the training to the learning styles of the residents. The third course included training in periodic interviews for the formative and summative assessment of residents. Participants in the courses were medical specialists from different specialties and hospitals in the Netherlands; among these participants were the gynecologists and pediatricians in our sample. We examined whether participation in one, two and three courses in the five years previous to the questionnaire had had any impact on adoptive behavior (Hypothesis 1).

Social network analysis: preparation of data for the social network independent variables

We used SNA techniques to measure the social network independent variables. Medical specialists rated their communication intensity with their fellow medical specialists in their own departments. The communication was specified "as communication in the past half year about the introduction of innovations, new methods or procedures, or new developments related to the work situation." The rating was on a six-point scale, ranging from "never," to "less than once a month," "once in three weeks," "weekly," "daily," or "more than once daily" (also used by Kratzer, 2001). The resulting data was analyzed using UCINET VI (Borgatti, Everett, & Freeman, 2002). The answers given by the respondents resulted in a directed valued graph and a matrix. "Directed" means that the relational tie (in this case, communication) of one person to another is either present or not. "Valued" means that the relational tie can range between "never" and "more than once daily." Graphs and matrices are useful techniques in SNA to represent social networks. In order to test the hypotheses, the data needed to be transformed into an undirected dichotomous matrix (or a symmetric matrix). We used the maximum symmetrizing method to convert the directed matrix into an undirected one and to correct for missing network data. This meant that the highest rating of communication intensity between two persons was used or, in the case of missing network data, the rating from one person. To dichotomize the valued matrix (ranging from 1 to 6), we recoded the scores as follows. The values one and two were recoded into zero, which means there is no communication. The values three, four, five and six were recoded into one, which means there is a communication relationship between medical specialists.

Strength of strong ties: degree centrality

Persons that have stronger ties to others are more central in the social network (Wasserman & Faust, 1994). Three centrality measurements can be distinguished: degree, betweenness and closeness. Degree centrality refers to persons who are the most visible in the network; these are persons who have a large degree of direct contact or are adjacent to many other persons and have strong ties with other people. Since this index captures direct or strong ties, we calculated it for every medical specialist and used it to test Hypothesis 2 (see Appendix 1 for the calculation of this index).

Strength of weak ties: betweenness centrality

Betweenness centrality refers to individuals who are literally on the communication paths between two other actors. These actors are central because they potentially control information between two non-adjacent persons (Wasserman & Faust, 1994). These persons are not necessarily strongly tied to other people. On the contrary, they have a lot of weak ties with a lot of people and serve as bridges for spreading information and resources between otherwise disconnected groups. This index represents the ratio of the number of times an actor is on the geodesics of other actors to the maximum amount possible. In other words, it represents the relative proportion that an actor is on the shortest path between two persons; therefore this index represents an actor's indirect or weak ties. We used the standardized index to test Hypothesis 3 and calculated this centrality measurement for every medical specialist (see Appendix 1 for the calculation of this index).

Strength of strong and weak ties: closeness centrality

Closeness centrality refers to persons who can quickly interact with all others; these actors can be very productive in communicating information to the other persons in the network (Wasserman & Faust, 1994). Persons with high closeness centrality have a great "reach" across the network. Closeness centrality can be viewed as persons who have both strong ties (high direct contacts) and weak ties (a lot of indirect ties). The index is the inverse of the sum of the distances from actor i to all other actors. As distances decrease the centrality index increases. This index captures both direct or strong ties and indirect or weak ties, since distances can be short (direct or strong ties) or long (indirect or weak ties). We standardized this index and used it to test Hypothesis 4 (see Appendix 1 for the calculation of this index).

Interviews: validation of the social network independent variables

All program directors of the different departments in our sample were interviewed to validate the social network and the individual centralities of the medical specialists found. Every social network was visualized for the six communication intensities and the program directors could indicate possible flaws in the network. For two networks, minor adjustments for individual centralities had to be made. Overall, the program directors strongly agreed with the social networks found.

Control variables

Numerous control variables may have an effect on social networks and innovation. The following are included in this study.

Gender

It has been widely recognized that social networks among men and women differ in complex ways, particularly in relation to life stage (Antonucci, 2001). Other studies have confirmed there is gender difference in social networks (Kunst & Kratzer, 2007).

Age

Age can influence social networks. Older people tend to have larger and older networks which are less geographically proximal (Ajrouch, Blandon, & Antonucci, 2005). Age difference in network structure may reflect differing roles and possibilities according to life stage.

Attitude

Meyers and Sivakumar (1999) hypothesized positive motivation, attitudes and commitment to the innovation as factors in facilitating implementation. They drew upon research done on management information systems, decision support systems, and telemarketing innovations. Attitude and motivation seem to be just as important in innovation adoption and implementation in health care as well (Garcia-Goni, Maroto, & Rubalcaba, 2007). Medical specialists rated the question, "Structured feedback is an improvement of the quality of postgraduate medical specialist education," on a five-point Likert scale ranging from "totally disagree" to "totally agree."

Hours of employment (part-time versus full-time employment)

An increasing number of health care professionals have part-time appointments. The influence of part-time employment on innovation is unclear. Weick and Martin (2006) found no significant differences between part-time and full-time "inventors." They seemed to be similar in terms of age, gender, educational level, and the types of inventions they pursued (Weick & Martin, 2006). Storey, Quintas, Taylor, and Fowle (2002) looked into the effect of flexible employment contracts on product and process innovations. It turned out that flexible working was found to be a consequence rather than a driver of innovation (Storey et al., 2002).

Length of employment in the organization

Relatively few studies have addressed length of employment in relation to innovation. Decker, Wheeler, Johnson, and Parsons (2001) found the longer a person worked in an organization, the more negative the scoring on job satisfaction, the effect of budget adjustments on individual job-related stress, the quality of individual performance, and department morale (Decker et al., 2001). On the other hand, the resource-based theorist would argue that organizations must build on and maintain the resources and capabilities needed to compete (Grant, 2001). Based on this it can be argued that length of employment actually has a positive influence on innovation.

Statistical analysis

To test for bivariate patterns in the data, we conducted an independent *t*-test for equality of means. Subsequently, we conducted a blockwise multiple regression analysis to assess multivariate patterns and to correct for partial correlations. Hierarchical linear modeling (multi-level analysis) was not used due to the limited number of departments in our sample (nine). At least ten observations on the highest level are necessary (Snijders & Bosker, 1999), but preferably more (Maas & Hox, 2005), in order to analyze the data using a random intercept model. The control variables were entered into the multiple regression model first, followed by the independent variables, according to the way they were presented in the theory and hypotheses development section of this paper. Betweenness centrality was transformed by a logarithmic transformation into a more normally distributed variable. Lastly, three interaction effects were entered into the model; these are the interactions between the Teach-the-Teacher training coefficients and the three centrality indexes. The assumptions of multicolinearity, independent errors and heteroscedascity were checked and the model was corrected for outliers. To achieve enough power and to minimize the possibility of a "type I error," we used a sample size of 81 in the regression analysis. This sample size is sufficient with regard to the expected effect size and the number of predictors in the model (Miles & Shevlin, 2001).

Results

From the total sample of 105 gynecologists and pediatricians, 95 responded to the questionnaire (90%). Ultimately a total of 81 gynecologists and pediatricians were included after deleting questionnaires with incomplete answers and those with outliers. From the total sample of 86 residents, questionnaires from all 63 respondents (73%) were included.

Reliability analysis yielded a Cronbach's alpha of .82 for the five questions that measured the dependent variable "structured feedback." Factor analysis revealed one construct under these questions (eigenvalue of 3.042 and 61% explanation of variance). The assumptions for factor analysis were met. There was no multicolinearity; the Kaiser–Meyer–Olkin measurement was .729 and Barlett's test was significant ($p < .01$). In Table 1 the descriptive statistics are presented.

Independent t-test

From the *t*-test results it follows that only closeness centrality causes significant differences ($p < .01$) in the average adoptive behavior (Table 2 and Figs. 1–5).

Regression analysis

The assumptions for regression analysis were met (Field, 2005). The residuals are independent (Durbin Watson is 1.536), there is no multicolinearity (VIF did not exceed 3.284 and the Pearson correlation did not reveal any correlations above .81), there is no heteroscedascity, and the residuals seem to be normally distributed. Table 3 shows the results for the regression analysis.

In the base model, age had a significantly negative relationship ($p < .01$) to adoptive behavior. The base model explains 11% of the variance in adoptive behavior. In Step 1 we entered the Teach-the-Teacher training participation coefficient. This caused no significant improvement in the model. Teach-the-Teacher training, therefore, had no significant relationship to adoptive behavior. In Step 2 we entered degree centrality to test the strong tie hypothesis. This significantly improved the model's fit ($p < .05$) with an additional 6.5%. Degree centrality had a significantly positive relationship ($p < .05$) to adoptive behavior. Betweenness centrality was entered in Step 3 (weak tie hypothesis) without significantly improving the model's fit. In the next step, closeness centrality (strong and weak tie hypothesis) was entered into the model, which led to an additional significant 10.5% improvement ($p < .01$) in the model's fit. Closeness centrality had a significantly positive relationship ($p < .01$) to adoptive behavior. After adding closeness centrality to the model, degree centrality was not significantly related to adoptive behavior anymore. In the last step, the interaction effects were entered into the model. This step caused no significant improvement to the model ($F = 2.288$, $p = .086$). We excluded this step from Table 3, since an interaction term is uninterpretable unless the overall *F* test reaches significance (Cohen,

Table 1
Descriptive statistics for medical specialists.

	n	Scale used	Min.	Max.	Mean	SE
Dependent variables						
Adoptive behavior	81	1–5	2.81	4.87	3.92	.46
Independent variables						
Teach-the-Teacher Training	81	0–3				
No course followed	26					
One course followed	55					
Two courses followed	18					
Three courses followed	7					
Degree centrality	81	0–100	15.79	100.00	77.41	22.35
Betweenness centrality (transformed)	81	0–100	.00	1.13	.30	.33
Closeness centrality	81	0–100	45.00	100.00	78.85	19.47
Control variables						
Gender	81					
Males	43					
Females	38					
Age	81	Years	31.00	63.00	47.45	8.02
Attitude	81	1–5	2.00	5.00	4.44	.69
Hours of employment (part-time vs. full-time)	81	%	50.00	100.00	91.05	11.85
Length of employment	81	Years	.12	29.00	9.67	7.37

West, & Cohen, 2002), and because the interaction effects are not included in the hypotheses.

Discussion

This study compared the contributions of Teach-the-Teacher training and social networks to the dissemination of an innovation in health care (adopting a novel structured feedback format to evaluate residents in training). No effect was found from a two to six day Teach-the-Teacher training course. This is in agreement with previous findings from a systematic review that found that student/resident evaluations did not always reflected the behavioral changes in teaching abilities participants perceived after following a faculty development program (Steinert et al., 2006). Although Teach-the-Teacher training can improve didactic knowledge and skills (Rubak et al., 2008), this by itself is apparently not enough to adopt the innovation successfully. On the other hand, we found a strong effect for social networks, with a strong association of closeness centrality to adoptive behavior both in the t-test and the regression analysis and a moderate effect of degree centrality for adoptive behavior in the regression analysis. Age was also important. With increasing age, medical specialists seem to be less likely to show adoptive behavior. It could be plausible that residents identify more with younger medical specialists. It is also possible that younger medical specialists are more familiar with structured feedback because their own medical training was already more oriented towards this innovation. Based on the findings, we had to reject Hypothesis 1 (effect of Teach-the-Teacher training) and Hypothesis 3 (weak ties). Hypothesis 2 (strong ties) and Hypothesis 4 (strong and weak ties) were accepted.

Table 2
Independent t-test results for adoptive behavior.

		n	Mean	SE	t	df
Independent variables						
Teach-the-Teacher training	No course followed	26	3.93	.41	.142	79
	One course followed	55	3.92	.48		
	No course followed	26	3.93	.41	.591	42
	Two courses followed	18	4.01	.41		
	No courses followed	26	3.90	.44	.453	32
	Three courses followed	7	3.99	.54		
Degree centrality	High (≥ mean (77.41))	45	4.00	.43	1.615	79
	Low (< mean (77.41))	36	3.83	.48		
Betweenness centrality	High (≥ mean (.30))	31	3.87	.48	−.852	79
	Low (< mean (.30))	50	3.96	.45		
Closeness centrality	High (≥ mean (78.85))	43	4.06	.45	3.124*	79
	Low (< mean (78.85))	38	3.76	.42		

*$p < .01$.

Network analysis

In this study, the medical specialists with both strong and weak ties were more likely to properly use the new structured feedback technique. This is in agreement with Burt (2004) who stated that both strong and weak ties were necessary. Weak ties are necessary for capturing innovations from outside the network and providing early access to diverse knowledge and resources, strong ties for implementing the innovations. It is also in agreement with Herzlinger (2006) who identified players (friends and foes) as a key driver or killer for innovations in health care. Friends and foes form the social networks which distribute innovations.

We found a significant contribution for degree centrality (strong ties) to the regression model until closeness centrality (strong and weak ties) was added. This is in line with Fattore et al. who found no significant relationship between a GPs degree centrality and performance (Fattore et al., 2009). The interaction effect between degree centrality and closeness centrality was not found in the bivariate t-test which legitimates the use of the more comprehensive multivariate regression analysis as an additional test. The interaction effect makes sense, since closeness centrality captures both strong and weak ties. One might expect the same interaction effect for betweenness centrality (weak ties). However, since this effect was not found, it can be concluded that strong ties are more important here than weak ties. There are a couple of explanations for these findings. Actors with more weak ties could experience information overload. Passing information along to others could be time-consuming. These actors are more oriented towards passing

Fig. 1. Boxplot for Teach-the-Teacher training on adoptive behavior.

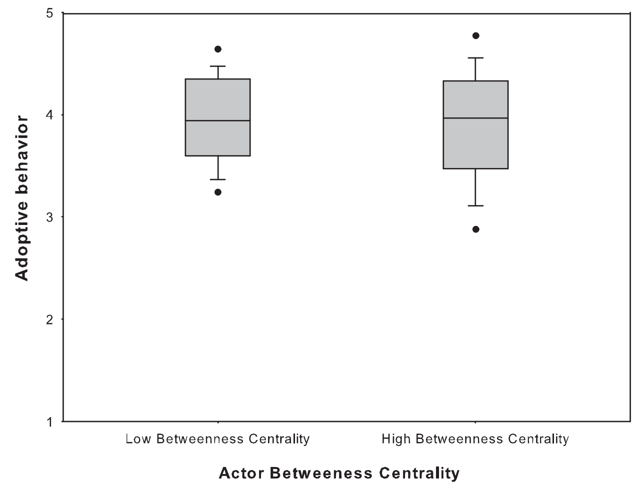

Fig. 3. Boxplot for betweenness centrality (weak ties) on adoptive behavior.

information along and have less time to adopt the innovation themselves properly (Kratzer, 2001). Since we measured proper adoption of the innovation and not first contact, this explanation could be plausible. Second, medical specialists are a relatively homophilous group; they are similar in educational background, job and social status (West & Barron, 2005). Homophily and communication reinforce each other: The more communication there is between members – or the stronger the tie between actors – the more likely they are to become homophilous (Rogers, 2003). So we could expect strong ties to play an important role in the adoption of innovations within the social networks of medical specialists. The third explanation could lie in the fact that the innovation studied – feedback technique – contains relatively complex information. Weak ties are more suitable for conducing relatively simple information and strong ties for diffusing complex information (Hansen, 2002). An important final explanation could be the connection with the Teach-the-Teacher training. Since medical specialists who followed the Teach-the-Teacher training course heard, saw and learned the new structured feedback technique, this innovation had already been introduced into the departments. In other words, there were no weak ties needed anymore to penetrate the departments.

We can draw the following conclusions. The most important factors influencing the diffusion of the new structured feedback technique among medical specialists are the strong and weak ties they have within their social networks. These seem to be more important than training and education. From a managerial point of view, it could be worthwhile to actively engage and compose social networks to disseminate innovations among health care professionals. We already know the importance of opinion leaders, gatekeepers, and lead users in innovation processes. In our paper we showed that it was possible to identify these key individuals using Social Network Analysis. After identification of these individuals, they can be harnessed for the dissemination of innovations. They can be incorporated in change initiatives, help to overcome resistance among their colleagues, and follow training and education on new health technologies and innovations. With regard to the innovation studied in this paper, it could make sense to incorporate medical specialists who have both strong and weak ties in Teach-the-Teacher courses. This may lead to effective and efficient dissemination to other medical specialists.

Limitations and suggestions for further research

This study had a number of limitations. First, we focused on the dissemination of innovations within teams of medical specialists regardless of whether the innovation originated inside or outside a specific team. The dissemination process within the teams could be influenced by social networks that medical specialists might have with other individuals outside their own team. These

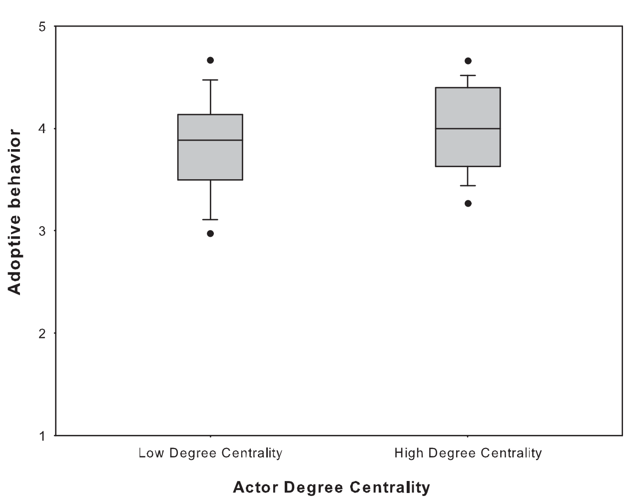

Fig. 2. Boxplot for degree centrality (strong ties) on adoptive behavior.

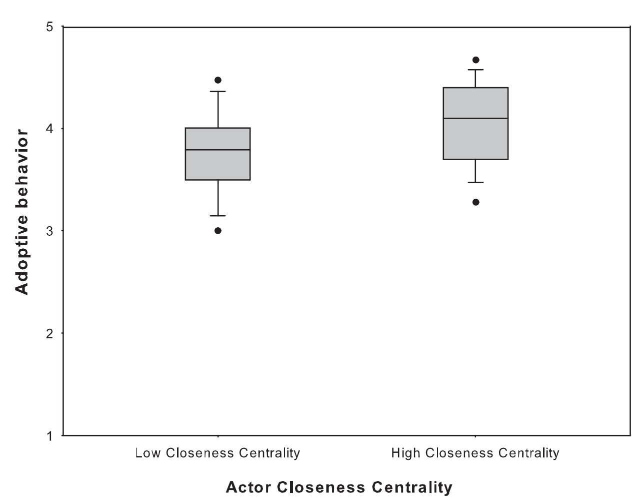

Fig. 4. Boxplot for closeness centrality (strong and weak ties) on adoptive behavior.

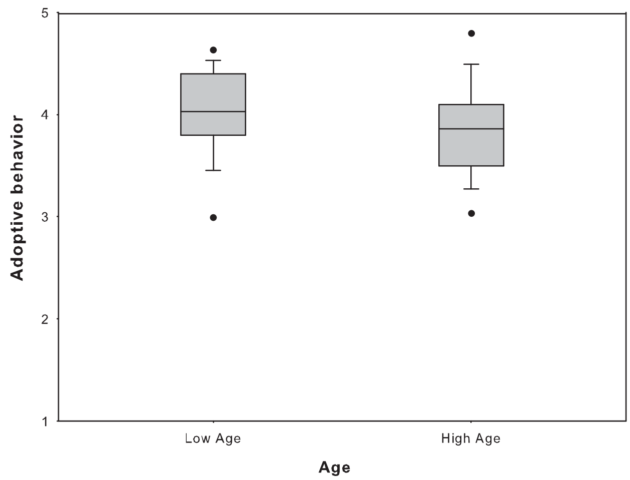

Fig. 5. Boxplot for age on adoptive behavior.

individuals range from medical doctors, to nursing staff, management, educationalists, and management consultants, as well as other support personnel. It would be interesting to examine how these networks are composed and what the effects are on the dissemination of health care innovations. Second, the study was carried out at the level of the individual, and not at the departmental level. For example, while we looked at individual degree centralities in departments, all individual degree centralities can also be aggregated into a group degree centralization index. This network level perspective could reveal important insights into the impact that the network structure has on effective diffusion and adoption of innovations in health care. Hospitals are characterized by high specialization, which leads to many informal social networks. Further studies are needed to investigate how these networks interact and how their composition can facilitate effective innovation. Third, this study had a relatively small sample size ($n = 81$) composed of two medical specialties. It would be interesting to examine whether the same conclusions could be drawn from a larger sample size that included more medical specialties. The inclusion of more departments would also make it possible to conduct hierarchical linear modeling. This might improve the model by accounting for the nested structure of the data and by adding departmental level independent variables. Fourth, the negative findings for Teach-the-Teacher training need to be interpreted with some caution. We did not work with an experimental design and we did not measure the effectiveness of the Teach-the-Teacher training with multiple criteria (e.g., Kirkpatrick's criteria of reaction, learning, behavior and results (Kirkpatrick & Kirkpatrick, 2006)). The primary endpoint here was the degree of adoptive behavior by medical specialists as assessed by their residents. Furthermore, the effectiveness of the Teach-the-Teacher training on the teaching behavior of the study participants was not studied. Fifth, we measured the social network relationships for new developments in the departments. To generate more richness in the nature of the social networks, further research might include different kinds of relationships (for example, collaboration, trust, and advice relationships) along with variables which can explain the social relationships found (for example, physical proximities and the personal characteristics of the respondents). A mixture of quantitative and qualitative techniques would be preferable in order to measure these variables. Finally, the study was limited to innovation in medical training. Although training and health care delivery are interwoven and the new structured feedback technique can have a direct impact on health care delivery, clinical errors and patient safety, we need to be cautious in generalizing the

Table 3
Regression analysis for adoptive behavior.

$n = 81$	B	SE	Beta
Base model			
Constant	5.23	.67	
Gender	−.09	.12	−.10
Age	−.03	.01	−.55**
Attitude	.03	.07	.04
Hours of employment	.00	.00	−.03
Length of employment	.02	.01	.35
Step 1: Hypothesis 1			
Constant	5.22	.68	
Gender	−.07	.13	−.08
Age	−.03	.01	−.51**
Attitude	.03	.08	.04
Hours of employment	.00	.00	−.03
Length of employment	.02	.01	.36
Teach-the-Teacher training	.05	.06	.09
Step 2: Hypotheses 2			
Constant	4.51	.71	
Gender	−.03	.13	−.03
Age	−.03	.01	−.51*
Attitude	.00	.07	.00
Hours of employment	.00	.00	.02
Length of employment	.02	.01	.33
Teach-the-Teacher training	.05	.06	.09
Degree centrality	.01	.00	.28*
Step 3: Hypothesis 3			
Constant	4.51	.71	
Gender	−.03	.13	−.03
Age	−.03	.01	−.51*
Attitude	.02	.07	.02
Hours of employment	.00	.00	.03
Length of employment	.02	.01	.33
Teach-the-Teacher training	.03	.06	.06
Degree centrality	.01	.00	.29*
Betweenness centrality (transformed)	−.22	.16	−.16
Step 4: Hypothesis 4			
Constant	4.34	.67	
Gender	−.09	.13	−.10
Age	−.03	.01	−.44*
Attitude	.02	.07	.03
Hours of employment	−.00	.00	−.06
Length of employment	.02	.01	.29
Teach-the-Teacher training	.05	.05	.10
Degree centrality	.00	.00	.01
Betweenness centrality (transformed)	−.30	.15	−.22
Closeness centrality	.01	.00	.43**

$R^2 = .102$ for base model ($p > .01$); ΔR^2 for step $1 = .008$ ($p > .05$); ΔR^2 for step $2 = .065$ ($p < .05$); ΔR^2 for step $3 = .021$ ($p > 005$) and ΔR^2 for step $4 = .105$ ($p < .01$). Total $R^2 = .302$.
*$p < .05$; **$p < .01$.

findings from this study to innovation in health care as a whole. The structured feedback technique can be defined as a complex incremental process innovation; complex, because adopters are asked to learn new non-medical knowledge and skills and integrate these into daily practice. Process innovations are new elements introduced into an organization's production or service operations in order to produce a product or render a service (Bareghen, Rowley, & Sambrook, 2009). The structured feedback technique improves the learning process of the resident and, therefore, improves the process of health care delivery. The focus of incremental innovations is on the renewal and improvement of existing products or services and technologies (Baregheh et al., 2009). The new structured feedback technique is a renewal of and an improvement on the existing medical specialty training programs. It would be interesting to examine the effects that network tie strength and social network structures have on different types of innovations (simple vs. complex, product vs. process, and imitative vs. radical) in medical education and primary health care processes.

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Appendix 1

Calculation degree centrality (strong ties)

Degree centrality is calculated as $DC(n_i) = x_{i+} = \sum_j x_{ij} = \sum_j x_{ij}$ where x_{ij} is the direct contact from actor i to actor j (Wasserman & Faust, 1994). We standardized this index with $DC(n_i)/g-1$ where g is the group size, and used to test Hypothesis 2.

Calculation betweenness centrality (weak ties)

Betweenness centrality is calculated as $BC\ (n_i) = \sum_{j<k} g_{jk}(n_i)/g_{jk}$ where $g_{jk}(n_i)$ is the number of geodesics (shortest path between two actors) that contain actor i and g_{jk} is the total number of geodesics present in the network (Wasserman & Faust, 1994). We used the standardized index $BC(n_i)/(g-1)(g-2)/2$ (where g is the group size) to test Hypothesis 3 and calculated this centrality measure for every medical specialist.

Calculation closeness centrality (strong and weak ties)

Actor closeness centrality is calculated as $CC(n_i) = [\sum_{j=1}^{g} d(n_i, n_j)]^{-1}$ where $d(n_i,n_j)$ is a distance function which captures the length of the geodesics from actor i to actor j (Wasserman & Faust, 1994). We standardized this index with $(g-1)$ $CC(n_i)$ (where g is the group size) and used it to test Hypothesis 4.

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