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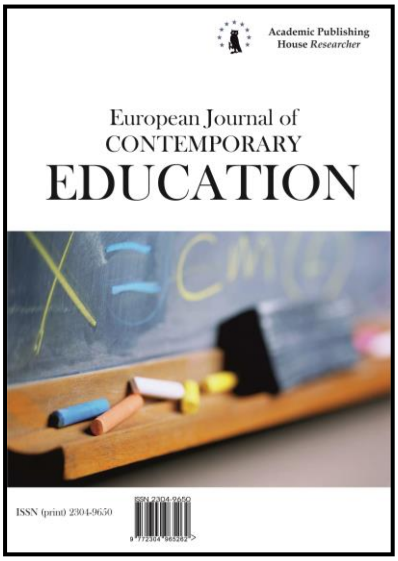

Innovative Work Activity of Science Teachers: the Pathway from New Ideas Generating to Sharing

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Abstract
The study addresses the phenomenon of science teachers' innovative work activities referring to Rogers' Diffusion theory of innovation (RDI) based on four countries (Sweden, Norway, Lithuania, Italy) TIMSS 2015 data set. The countries were chosen according to different criteria: 1–years of teaching; 2 – gender; 3 – hours spent for professional development. According to RDI, the innovation process consists of five stages: Knowledge, Persuasion, Decision, Implementation, and Confirmation. Different innovative work activities occur at different stages of innovation process: to generate, to champion, to apply, to promote, and to share new ideas. The aim of the article is to reveal the internal structure of innovative work activity of science teachers, highlighting the associations of innovative work activities on each other. TIMSS 2015 the instrument for science teachers allowed carrying out empirical analysis of science teachers' innovative work activities. All variables of our interest in innovative work activities of science teachers were directly observable. Taking this into account a path analysis was used. According to the findings of the path analysis all innovative work activities of science teachers directly and positively influence each other. We argue that new idea generation activity of science teachers directly and indirectly influences new ideas sharing activity. The direct effect of new idea generating activity on new idea sharing activity is stronger than the indirect effect.
Keywords: innovative work behavior, innovative work activity, science teacher, science education.

1. Introduction

Innovation is a distinctive feature of a creative society (Florida, 2002; Obeng, 2019). Humans with the abilities for innovation are able to create new products, to compete in the economy sector (Obeng, 2019; Wisetsat, Nuangchalerm, 2019). Educational institutions are part of a creative society: teachers are key actors in educating students for an innovation-driven society. Teachers

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must not only be able to apply innovation in the educational process but also be able to develop students' innovative work abilities (Klaeijsen et al., 2018; Wisetsat, Nuangchalerm, 2019). Science teachers play an important role in this process, because "Innovation in science education is less a characteristic of a particular period in time than a normal and continuing process" (Layton, 1986: 9).

Innovation in science education manifests itself in two ways: curriculum content and teaching methods (Adams et al., 2018). In the light of science education reforms (NRC, 1996; NRC, 2000; NRC, 2012) there have been growing calls for innovation associated with teaching methods. Innovation in science education has focused on scientific inquiry, discovery, and constructivist approaches (Furtak, Kunter, 2012). Oyelekan et al. (2017) define innovative teaching as a form of guided discovery in which the teachers attempt to lead students to discuss, discover, and verbalize new knowledge. The implementation of constructivist approaches in science education depends on the innovative work behavior of science teachers (Adams et al., 2018).

Rogers' Diffusion theory (Rogers, 2003) of innovation process helps to understand the structure of innovative work activity of science teachers. According to Rogers' Diffusion of innovations theory (RDI), the innovation process is composed of five stages: Knowledge, Persuasion, Decision, Implementation, and Confirmation (Rogers, 2003). The different innovative work activities occur at different stages: new ideas generating activity (Knowledge, Persuasion, Decision stage), and new ideas implementation activity (Implementation stage, Confirmation stage). It follows from RDI that innovative work activity is a complex and multi-dimensional construct (Scott, Bruce, 1994). Seeking to improve and manage the innovative work activity of science teachers, it is necessary to understand its internal structure and to anticipate the interrelationship of its structural components.

An analysis of the scientific literature on the innovative work activity of science teachers from the view of RDI revealed that the innovative activity of science teachers is manifested by the interest in innovation while searching for information about innovations (Exner, 2014), the application of new learning methods (Akhter, Fatima, 2016; Etkina et al., 2010; Lowe et al., 2013; Okada et al., 2015; Okada, 2016; Riga et al., 2017), and the dissemination of the application of innovations in education (Okada et al., 2015; Train, Miyamoto, 2017). However, there is a lack of a systematic approach to science teachers' innovative work activity, and to the research about the internal relationship of innovative work activities.

The situation about innovations in science education is highlighted in the New Consortium Media (Adams et al., 2018), Measuring Innovation in Education monitoring (OECD, 2019). An innovation survey (Halász, 2018). OECD (2019) uses TIMSS 2015 (The Trends in International Mathematics and Science Study) data for secondary analysis of educational innovations in science education and presents the results of a longitudinal study about the implementation of innovations.

We aim to contribute to the field of educational innovations by analyzing innovative work activities of science teachers on the basis of RDI in order to reveal the internal structure of innovative work activity, from new ideas generation to their implementation and sharing. The aim of the article is to reveal the internal structure of innovative work activity of science teachers, highlighting the associations and influence of innovative work activities on each other.

2. Theoretical background

2.1. The concept of innovative work behavior and innovative work activity

The construct of innovative work activity is inseparable from the phenomenon of innovative work behavior. There are two approaches to innovation in the scientific literature: on the one hand, innovation is treated as a process, on the other hand – as a result (Messmann, Mulder, 2012). Innovative work behavior describes the role of individuals in the innovation process (West, Farr, 1989; West, Farr, 1990). Farr and Ford (1990) defined innovative work behavior as an individual's abilities to initiate new and useful ideas, processes, and to produce new products. Scholars described innovative work behavior as the development and implementation of new ideas to solve a particular problem or improve an existing situation in an activity (Messmann, Mulder, 2011, Messmann, Mulder, 2012; Scott, Bruce, 1994).

Innovative work behavior reflects a series of activities in which individuals generate novel ideas, solve practical problems at work and achieve positive effects innovation tasks. Scholars state, that innovative work behavior encompasses all physical and cognitive work activities of individuals

(Messmann, Mulder, 2014; Sun, Huang, 2019). An in-depth understanding of innovative work activity requires an analysis of innovative work behavior. Different models can be found in the scientific literature that describe the structure of the dimensions of innovative work behavior of individuals (De Jong, Den Hartog, 2010; Janssen, 2003; Kleysen, Street, 2001; Messmann, Mulder, 2012; Patterson, 2002; Rogers, 2003; Scott, Bruce, 1994; Serdyukov, 2017; Sun, Huang, 2019; Thurlings et al., 2015).

The analysis of the scientific literature highlighted a lot of innovative work behavior activities of individuals: the situation recognition (De Jong, Den Hartog, 2010; Messmann, Mulder, 2012); the problem recognition (Dorenbosch et al., 2005; Farr, Tran, 2008; Scott, Bruce, 1994); ideas generation (De Jong, Den Hartog, 2010; Dorenbosch et al., 2005; Farr, Tran, 2008; Kleysen, Street, 2001; Messmann, Mulder, 2012; Patterson, 2002; Scott, Bruce, 1994); ideas formulation (Farr and Tran, 2008; Patterson, 2002); ideas championing (Dorenbosch et al., 2005; Messmann, Mulder, 2012; Scott, Bruce, 1994); ideas implementation (De Jong, Den Hartog, 2010; Dorenbosch et al., 2005; Farr, Tran, 2008; Kleysen, Street, 2001; Messmann, Mulder, 2012; Patterson, 2002; Scott, Bruce, 1994); and new ideas reflection (Messmann, Mulder, 2012). Consequently, there is no unified, single approach to the innovative work activity. In the diversity of approaches of innovative work activity, general trends can be seen. Researchers usually distinguish two main innovative work activities – the generation and the implementation (realization) of new ideas (Gong et al., 2013; Kleysen, Street, 2001). However, only a small body of research has examined the associations between innovative work activities.

2.2. The concept of innovative work activity according to RDI

The process of innovation starts with the Knowledge stage (Rogers, 2003) (Figure 1). De Jong and Hartog (2010) argue that every innovation in the beginning has a trigger: "the discovery of an opportunity or some problem arising" (p. 24). Drucker (1985) described seven sources (triggers) of innovation from unexpected successes till changes in perception and new knowledge. The most important triggers in the activities of science teachers are gaps between "what is" and "what should be", changes in perception, and new knowledge. The possibilities of science teachers to play with these triggers depend on science teachers' idea exploration abilities.

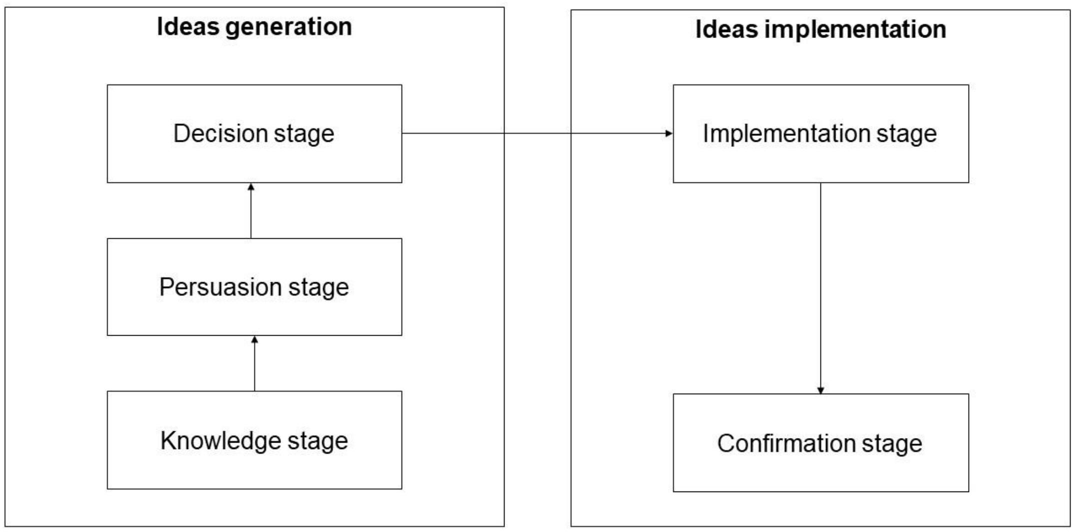

Fig. 1. The main stages of innovation process. The simplified Rogers (2003) model of Five Stages in the Innovation-Decision Process

According to RDI, the second stage of innovation is Persuasion (Figure 1). At the Persuasion stage "the formation of a favorable or unfavorable attitude toward an innovation does not always lead directly or indirectly to an adoption or rejection" (Rogers, 2003: 176). Rogers (2003) states that the Persuasion stage is more affective, the individuals are involved in communication with others (colleagues, peers) in order to get the individual's opinions and beliefs about the innovation.

At the Persuasion stage the new ideas generation abilities. The idea generation abilities require "kaleidoscopic thinking", as idea persuasion often involves rearranging already existing pieces into a new whole (De Jong, Hartog, 2010). The communication channels with other individuals help develop "kaleidoscopic thinking", and new idea generating abilities (Rogers, 2003).

The Decision stage is third in the innovation process (Figure 1). A further implementation of innovation depends on this stage: "full use of an innovation as the best course of action available," or rejection of innovation – "not to adopt an innovation" (Rogers, 2003: 177). It should be noted that the order of the knowledge-persuasion-decision stages may be different: knowledge-decision-persuasion (Rogers, 2003). Ideas championing abilities of individuals become relevant at this stage. Scholars state that championing includes finding support and building enthusiasm and confidence about the success of the innovation (Howell et al., 2005). In this step, the degree of uncertainty rests on new ideas, and social reinforcement from other colleagues is needed. To reduce the level of uncertainty the teachers visit another classroom to learn more about teaching, seeking to see how innovation works. Sherry (1997) states that "While information about a new innovation is usually available from outside experts and scientific evaluations, teachers usually seek it from trusted friends and colleagues whose subjective opinions of a new innovation are most convincing" (Sherry, 1997: 70).

New ideas need to be implemented. According to RDI, the fourth stage of the innovation process is the implementation of ideas in practice (Figure 1). The implementation of new ideas makes innovation a part of traditional work processes (Kleysen, Street, 2001). The ability to implement new ideas manifests itself by the developing new products or work processes, testing, and modifying them (Kanter, 1988).

At the new ideas' implementation stage "some degree of uncertainty is involved in diffusion" (Rogers, 2003: 6). This uncertainty disappears at the confirmation stage of innovation (Figure 1). At this stage individuals share information about implementation of new ideas and seek supportive messages that confirm innovations. "Thus, attitudes become more crucial at the confirmation stage. Depending on the support for adoption of the innovation and the attitude of the individual, later adoption or discontinuance happens during this stage" (Sahin, 2006: 17). The shared new information becomes the trigger for new innovations and the resource of knowledge.

2.3. Science teachers' innovative work activity

An analysis of the literature shows that researchers discuss the application of innovations in science education (Laudonia et al., 2018; Leeuwis, Aarts, 2016; Mestrinho, Cavadas, 2018; Ng et al., 2019). Scholars analyze the role of science teachers' self-efficacy in innovation (Dede et al., 2017); highlight the influence of communication on innovation of science education (Eilks et al., 2010); look for the implementation of responsible research and innovation (RRI) in science education (Bayram-Jacobs, 2015; Heras, Berrens, 2020; Ocada, 2016; Okada, Sherborne, 2018; Ruiz-Mallén et al., 2020); discuss science education and ICT innovation (Rusek et al., 2017); analyze innovative thinking of science teachers (Wisetsat, Nuangchalerm, 2019); and argue about innovative strategies in science teaching (Oyelekan et al., 2017). Analyzing the research findings on the application of innovations in the educational practice of science subjects, it has to be stated that researchers are more often interested in the external side of innovations – the application of innovations. It should be noted that there is a lack of research on internal side of innovations – the innovative work activities of science teachers, the associations between innovative work activities.

2.4. Research questions and Hypothesis

The international TIMSS 2015 study provides an opportunity to investigate the expression of innovative work activities of science teachers, and to determine the associations of different activities of science teachers' in science education. We developed five hypotheses (H_n) on the basis on the theoretical concepts:

H_1: Science teachers' activity to generate new ideas positively and directly affects science teachers' activity championing new ideas.

H_2: Science teachers' activity to champion new ideas positively and directly affects the activity to apply new ideas.

H_3: Science teachers' activity to apply new ideas positively and directly affects the activity to promote new ideas.

H_4: Science teachers' activity to promote new ideas positively and directly affects science teachers' activity to share new ideas.

H_5: Science teachers' activity to generate new ideas positively and directly affects science teachers' activity to share new ideas.

3. Methodology and methods

3.1. Instrument of research

TIMSS 2015 secondary data analysis was performed according to the theoretical model of science teachers' innovative work activities using the AMOS (Analysis of Moment Structures) software. TIMSS 2015 Instrument for science teachers allowed carrying out empirical analysis of science teachers' innovative work activities. We selected two complex questions from the TIMSS 2015 questionnaire corresponding to RDI theory: the question about science teachers' work activities and communication (BTBG 09A-BTBG 09G); the question about teaching activities in the classroom (BTBG 14A-BTBG 14G). We performed exploratory factor analysis (EFA) with Varimax (orthogonal) rotation (see Appendix). Factorability of science teachers' innovative work behavior was examined. The Kaiser-Meyer-Olkin test (KMO-test) revealed sampling adequacy. It was disclosed that (KMO = 0.883 <.05) for observed variables. Intercorrelation was checked by using Bartlett's test of (χ^2 (91) = 4260.403, $p < .05$). A principal component analysis (PCA) of science teachers' work activities yielded into three factors explaining a total of 55.54 % of the variance for the entire set of variables. The first factor was labelled innovative work activity due to the high loadings by the items about innovative work activities. This first factor explained 33.78 % of the variance. The factor Innovative work activity encompasses the questions about science teachers innovative work activities (BTBG 09E; BTBG 09D; BTBG 14F; BTBG 14G; BTBG 09C) (Table 1).

Table 1. Science teachers' innovative work activity: question content from TIMSS 2015

Innovative work activity	Question code	Question content from TIMSS 2015
Generation of new ideas	BTBG09E	Work together to try out new ideas
Championing of new ideas	BTBG09D	Visit another classroom to learn more about teaching
Applying of new ideas	BTBG14F	Ask students to decide their own problem-solving procedures
Promotion of new ideas	BTBG14G	Encourage students to express their ideas in class
Confirmation and sharing new ideas	BTBG09C	Share what I have learned about my teaching experiences

3.2. Sample and normality data

We tested the Path analysis model (Figure 2) using TIMSS 2015 data from four countries (Norway, Sweden, Lithuania, Italy). The countries were chosen according to different criteria: 1– years of teaching; 2 – gender; 3 – hours spent for professional development.

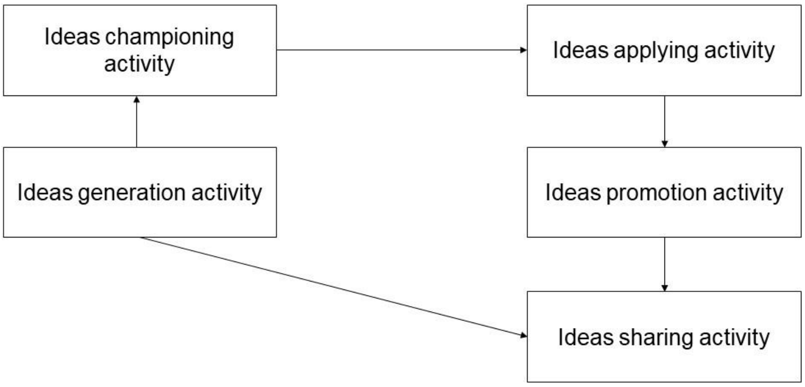

Fig. 2. Path analysis framework of science teachers' innovative work activities.

All variables of our interest in innovative work activities of science teachers are directly observable (Table 1). Taking this into account a path analysis was used. The strength of a path analysis lies in its ability to decompose the relationships among variables and to test the credibility of a theoretical perspective. A model of path analysis was developed (Figure 2) based on RDI.

We have chosen two countries each where the data of science teachers are similar according to the first (years of teaching) and the second (gender) criterion. The first group was Sweden and Norway, the second group – Italy and Lithuania (Table 2). Professional development (PD) hours of science teachers were similar in the first group of countries (Sweden and Norway), but they were diametrically opposite in Lithuania (Table 2).

Table 2. The years been teaching, the gender, and the professional development hours of science teachers

	Italy	Norway	Lithuania	Sweden
Years been teaching				
Mean	22.69	12.13	24.54	12.92
Median	24.00	10.00	25.00	12.00
Gender				
Male	21.8	44.7	12.7	40.7
Female	76.7	55.3	87.3	59.3
PD hours in two years				
None	35.0	57.4	2.9	33.5
Less than 6 hours	24.3	19.5	7.3	27.0
6–15 hours	21.4	10.5	31.5	22.5
16–35 hours	11.2	4.7	30.3	7.2
More than 35 hours	7.8	7.4	28.0	9.7

The normality of questions data (Table 1) was checked using values of asymmetry (skewness and kurtosis) (Table 3). The values for asymmetry (skewness and kurtosis) between -2 and +2 are considered acceptable in order to prove normal univariate distribution (George, Mallery, 2010).

Preliminary results of the data normality from different countries showed that the data did not meet the conditions of normality well. Using box plots exceptions were investigated and such data were removed. The normality of data was rechecked after removal of exceptions. Asymmetry coefficients indicate that the data satisfies the condition of normality (Table 3). Samples differ in size from country to country (Table 3). The smallest sample size is from Norway, the largest – from Lithuania. The removal of exceptions did not much change the samples size. For example, the original Norwegian database contained 195 subjects: after removing exceptions – 190 subjects (Table 3).

Table 3. Normality of science teachers' innovative work activities data: asymmetry coefficients test

		Question code (BTBS)				
Country/ sample size	Asymmetry coefficients	BTBG09E	BTBG09D	BTBG14F	BTBG14G	BTBG09C
		Generate	Develop	Applying	Promote	Share
Italy/ 206	Skewness	-.447	-1.426	.646	1.271	-.118
	Kurtosis	-.235	1.334	-.983	.159	-.613
Lithuania/ 945	Skewness	-.649	-.617	-.491	1.488	-.262
	Kurtosis	.468	.942	-.526	1.231	-.521
Sweden/ 617	Skewness	-.263	-.633	-.445	.658	.184
	Kurtosis	-.633	-.607	-.435	-.933	.746
Norway/190	Skewness	-.370	-.807	-.782	.220	.181
	Kurtosis	.140	-.401	-.223	-.794	.892

3.3. The fitness of data for path analysis

The model contains the following variables: observed, exogenous variable is the activity to generate new ideas; observed, endogenous variables are the activities to champion, to apply, to promote, and to share new ideas.

We used numerous goodness-of-fit indicators to assess a model of science teachers' innovative work behavior (Table 4). Those values indicate a good fit between the model and observed data from different countries.

Table 4. The fitness of items of science teachers' innovative work activities

Country		Absolute fit index			Relative fit index		
		χ2/df	RMSEA	GFI	IFI	TLI	CFI
Italy	Assumed model	1.585	.000	.877	.993	.982	.993
	Acceptance value	1-5	<.08	>.80	>.90	>.90	>.90
Lithuania	Assumed model	0.784	.079	.994	.992	.962	.992
	Acceptance value	1-5	<.08	>.80	>.90	>.90	>.90
Norway	Assumed model	1.481	.037	.877	.999	.992	.999
	Acceptance value	1-5	<.08	>.80	>.90	>.90	>.90
Sweden	Assumed model	3.797	.067	.901	.986	.953	.986
	Acceptance value	1-5	<.08	>.80	>.90	>.90	>.90

4. Results

In this study, we tried to reveal the internal structure of science teachers' innovative work activity. We were interested in how much the innovative work activities of science teachers are affected by each other and what are the direct and indirect effects of science teachers' new ideas generation activity on teachers' new idea sharing activity.

The results of multiple regression analysis were described using unstandardized and standardized coefficients (Tables 5–8). The unstandardized beta (*B*) represents the value of predictor variable and the dependent variable. The standardized regression coefficient (β) indicates relationships according to the order of variables in terms of their significance: new ideas generation and new idea championing; new ideas championing and new ideas applying; new ideas applying and new ideas promoting, new ideas promoting and new ideas sharing, new ideas generations and new ideas sharing. The probability level (p) tells whether or not an independent variable significantly predicts the dependent variable (Tables 5–8).

The findings of our quantitative study (p value) on the basis of TIMSS 2015 data from Italy (Table 5) revealed that science teachers' activity to generate new ideas directly and positively affects the activity to champion new ideas (B = .303), (R^2 = .156, p < .01); the activity to apply new ideas affects science teachers' activity to promote new ideas (B = .405), (R^2 = .188, p < .01); Science teachers' activity to generate new ideas directly affects science teachers' activity to share new ideas (B = .614), (R^2 = .369, p < .01). The greatest value of R^2 is at H_5 hypothesis (Table 5). This means that 36.9 % of science teachers' activity to share new ideas was influenced by science teachers' activity to generate new ideas in teaching science. The remaining 63.1 % changes are influenced by other factors.

Table 5. The paths' coefficients and statistical significance of science teachers' innovative work activities: on TIMSS 2015 data from Italy

Hypothesis	Paths	B	S.E.	β	p	R^2	Results
H1. Science teachers' activity to generate new ideas affects science teachers' activity to champion new ideas.	BTBG09E → **BTBG09D**	.303	.049	.395	***	.156	Support
H2. Science teachers' activity to champion new ideas affects science teachers' activity to apply new ideas.	BTBG09D→ **BTBG14F**	.018	.083	.029	.633	.001	Not support
H3. Science teachers' activity to apply new ideas affects science teachers' activity to promote new ideas.	BTBG14F→ **BTBG14G**	.405	.059	.434	***	.188	Support
H4. Science teachers' activity to promote new ideas affects science teachers' activity to share new ideas.	BTBG14G→ **BTBG09C**	.157	.064	.101	.052	.019	Not support
H5. Science teachers' activity to generate new ideas affects science teachers' activity to share new ideas.	BTBG09E→ **BTBG09C**	.614	.054	.609	***	.369	Support

The data of TIMSS 2015 from Lithuania (Table 6) revealed that science teachers' activity to generate new ideas also directly and positively affects the activity to champion new ideas (B = .596), (R^2 = .374, p < .01), Science teachers' activity to generate new ideas directly and positively affects science teachers' activity to share new ideas (B = .469), (R^2 = .223, p < .01). The probability level (p) tells that in testing hypothesis H_2, H_3, H_4 an independent variable significantly predicts the dependent variable, but values of R^2 are very small and vary from 4.7 %

to 6.8% (Table 6). R^2 indicate that there was no predictable meaningful effect on dependent variables: activity to apply new ideas; activity to promote new ideas; activity to share new ideas.

Table 7 shows the results of multiple regression analyses of innovative work activities of science teachers from Sweden. TIMSS 2015 data from Sweden confirmed the previous tendency from Italy and Lithuania: the science teachers' generation of new ideas directly and positively affects the activity to champion new ideas (B = .346), (R^2 = .215, p < .01); Science teachers' activity to generate new ideas affects science teachers' activity to share new ideas (B = .585), (R^2 = .412, *p* < .01) (Table 7).

Table 6. The paths' coefficients and statistical significance of science teachers' innovative work activities: on TIMSS 2015 data from Lithuania

Hypothesis	Paths	B	S.E.	β	p	R^2	Results
H1. Science teachers' activity to generate new ideas affects science teachers' activity to champion new ideas.	BTBG09E → **BTBG09D**	.596	.025	.612	***	.374	Support
H2. Science teachers' activity to champion new ideas affects science teachers' activity to apply new ideas.	BTBG09D→ **BTBG14F**	.250	.038	.217	***	.047	Support
H3. Science teachers' activity to apply new ideas affects science teachers' activity to promote new ideas.	BTBG14F→ **BTBG14G**	.207	.025	.260	.005	.068	Support
H4. Science teachers' activity to promote new ideas affects science teachers' activity to share new ideas.	BTBG14G→ **BTBG09C**	.127	.032	.112	***	.049	Support
H5. Science teachers' activity to generate new ideas affects science teachers' activity to share new ideas.	BTBG09E→ **BTBG09C**	.469	.030	.455	***	.223	Support

Table 7. The paths' coefficients and statistical significance of science teachers' innovative work activities: on TIMSS 2015 data from Sweden

Hypothesis	Paths	B	SE	β	p	R^2	Results
H1. Science teachers' activity to generate new ideas affects science teachers' activity to champion new ideas.	BTBG09E→ **BTBG09D**	.346	.027	.463	***	.215	Support
H2. Science teachers' activity to champion new ideas affects science teachers' activity to apply new ideas.	BTBG09D→ **BTBG14F**	.215	.047	.181	***	.032	Support
H3. Science teachers' activity to apply new ideas affects science teachers' activity to promote new ideas.	BTBG14F→ **BTBG14G**	.342	.036	.345	***	.124	Support
H4. Science teachers' activity to promote new ideas affects science teachers' activity to share new ideas.	BTBG14G→ **BTBG09C**	.145	.034	.133	***	.040	Support

H5. Science teachers' activity to generate new ideas affects science teachers' activity to share new ideas.	BTBG09E→ **BTBG09C**	.585	.024	.624	***	.412	Support

According to small square multiple correlation R^2 values, there was no meaningful relation between science teachers' activity to champion new ideas and science teachers' activity to apply new ideas R^2 = .032; science teachers' activity to apply new ideas and science teachers' activity to promote new ideas R^2 = .124; science teachers' activity to promote new ideas and science teachers' activity to share new ideas R^2 = .040 (Table 7).

The findings on the basis of TIMSS 2015 data from Norway confirmed that science teachers' generation of new ideas directly and positively affects the activity to champion new ideas (B = .381), (R^2 = .196, p < .01); Science teachers' activity to generate new ideas directly affects science teachers' activity to share new ideas (B = .573), (R^2 = .314, p < .01) (Table 8).

Table 8. The paths' coefficients and statistical significance of science teachers' innovative work activities: on TIMSS 2015 data from Norway

Hypothesis	Paths	B	SE	β	p	R^2	Results
H1. Science teachers' activity to generate new ideas affects science teachers' activity to champion new ideas.	BTBG09E → **BTBG09D**	.381	.060	.420	***	.196	Support
H2. Science teachers' activity to champion new ideas affects science teachers' activity to apply new ideas.	BTBG09D→ **BTBG14F**	.274	.083	.233	***	.054	Support
H3. Science teachers' activity to apply new ideas affects science teachers' activity to promote new ideas.	BTBG14F→ **BTBG14G**	.473	.071	.435	***	.109	Support
H4. Science teachers' activity to promote new ideas affects science teachers' activity to share new ideas.	BTBG14G→ **BTBG09C**	.118	.031	.131	.028	.024	Support
H5. Science teachers' activity to generate new ideas affects science teachers' activity to share new ideas.	BTBG09E→ **BTBG09C**	.573	.062	.549	***	.314	Support

We were especially interested in the direct and indirect effect of new ideas generation activity on new ideas sharing activity (Table 9). On the one hand, we hypothesized that new ideas generation activity directly affects new ideas sharing activity (H_5). On the other hand, we hypothesized that the relationship between new ideas generation activity and new ideas sharing activity was mediated, and has an indirect effect on new ideas sharing, by others' activities (Figure 2).

Table 9. Results from Path analysis: Effect of new ideas generation activity on new ideas sharing activity

Country	Effect	β	B	SE	R^2
Italy	Direct	.603	.595	.054	.375
	Indirect	.001	.000		
	Total	.604	.595		
Lithuania	Direct	.455	.469	.030	.223

	Indirect	.004	.004		
	Total	.459	.473		
Sweden	Direct	.624	.585	.029	.412
	Indirect	.004	.004		
	Total	.628	.589		
Norway	Direct	.549	.573	.062	.325
	Indirect	.006	.006		
	Total	.555	.579		

The data of different countries (Italy, Lithuania, Sweden, Norway) show that the direct effect on new ideas sharing activity is stronger than the indirect effect (Table 9), despite the similarities and differences between the science teachers according to the chosen criteria (the years of teaching; the gender; hours spent for professional development).

According to the findings, there was a statistically significant direct and positive effect of all innovative work activities on each other. It can be argued that the activity of science teachers to generate new ideas determines the activity to champion new ideas (β varies from .395 to .612); the ability to champion new ideas determines the activity of science teachers to apply new ideas in practice (β varies from .181 to .233); the activity to apply new ideas determines the activity to promote a new idea (β varies from .260 to .434); the activity to promote new ideas determines the activity to confirm new ideas by sharing new information (β varies from .112 to .133); the ability to generate new ideas determines the activity to confirm new ideas by sharing new information (β varies from .455 to .624); (Tables 5, 6, 7, 8).

Summarizing the results of the TIMSS 2015 study on the innovative behavior of science teachers in different countries (Italy, Lithuania, Sweden, Norway), it should be noted that a path analysis results support well the hypotheses H_1, H_5. According to probability level (p), other hypotheses (H_2, H_3, H_4) also were confirmed (except H_2, H_4 on Italy data), but square multiple correlation R^2 values are very small. This is quite low, so predictions from the regression equation are not fairly reliable.

5. Discussion

In this study, on the basis of Rogers Diffusion theory (2003), we tried to reveal the structure of science teachers' innovative work activity and to define how much the innovative work activities affect each other. We selected countries whose teachers differed by the years of teaching (Norway, Lithuania), by hours spent for continuous professional development (Lithuania, Italy, Norway, Sweeden). However, the pathways analysis of innovative work activity did not reveal statistically significant differences in the analyzed countries. Our research has shown how one innovative work activity is associated with another according to RDI theory and encourages further research, highlighting the links between the years of teaching, the gender, and the innovative work activities of science teachers. Our study was conducted with databases of countries where the duration of professional development of science teachers was different (for example Lithuania and Norway). However, the results of the path analysis of the innovative work activities of science teachers in those countries do not differ. This encourages a new look at the duration and the content of professional development. The research results allow to stipulate that less emphasis should be placed on the duration of professional development and pay more attention to the content of innovative work activities and the associations between them in professional training of science teachers.

Consequently, there were direct and indirect effects of new ideas generation on new ideas sharing activity of science teachers. Results from a path analysis revealed the stronger role of direct effect of new ideas generation activity on new ideas sharing activity (Table 9). This result has a theoretical background from the Amabile (1983) componential theory which states that a person's production of new ideas is influenced by the person's creativity, domain-relevant knowledge, a person's perceived value of engaging in the task itself. The dissemination of new ideas takes place through communication and depends on science teachers' creativity, and also on domain-related knowledge. Communication fosters creative thinking which causes the ability to generate new ideas (Harris, de Bruin, 2018). This result has an educational background from brainstorming, collaborative creativity sessions, group creativity (Paulus et al., 2012). According to Baruah and

Paulus (2019), "group creativity combines cognitive processing and group members build on each other's ideas to generate more and better ideas" (p. 157).

Innovative teachers' work activity is associated with innovative thinking (Wisetsat, Nuangchalerm, 2019). We observe the above-mentioned aspects of innovative thinking in RDI theory: exploration (interpret) of new ideas, generation (generate) of new ideas, championing (collaborate, reflect) of new ideas, and implementation (represent, evaluate) of new ideas. Wisetsat and Nuangchalerm (2019) analyzed the innovative thinking of Thai pre-service teachers through multi-educational innovations and revealed 6 steps for promoting the innovative thinking of pre-service teachers: setting goals, brainstorming, innovation design, reflection, teaching, and evaluation. It would be useful to explore teachers' innovative work activities at each step of innovative thinking.

We believe that other trends could emerge in the study of innovative work activities by teachers of other subjects according to the RDI-based model. Hence, future researchers should focus on innovative work activities of other subject teachers. In addition, the abilities of innovative work activities can be determined not only by the subject, but also by the teachers' relationship with ICT. Rogers (2003) uses the term innovation as a synonym for technology. Yeh et al. (2015) distinguished three groups of teachers according to their proficiency in using ICT: technology-infusive (TI), technology transitional (TR), and planning and design (PD). Rusek et al. (2017) state that "the TI teachers were more student-centered, whereas the TR teachers were more teacher-centered. The PD teachers were proficient in planning and designing but expressed lower evenness in their answers than TI and TR" (p. 510). It would be valuable to study the structure of innovative work activities of TI teachers, TR teachers, and PD teachers, revealing the peculiarities of innovative work activities according to RDI theory.

A pathway analysis can be applied to study the teachers' innovative work activities according to the classification of innovation adopters proposed by Rogers (2003): innovators, early adopters, early majority, late majority, and laggards. It would be useful to examine what are the innovative work activities (new ideas generation, championing, applying, promoting, and dissemination) of teachers from different innovation adopters' groups.

Rusek et al. (2017) compared Rogers' (2003) innovation adopters' model with Yeh et al. (2015) teachers' proficiency using information and communication technology (ICT) model: "innovators (comparable with PD-teachers), early adopters, early majority, late majority, laggards (comparable with TI-teachers)". Rusek et al. (2017) analyzed how ICT is used in chemistry education and revealed that Innovators represent 23 % of the pre-service chemistry teachers, only 3 % of respondents are laggards – the most traditional, conservative group. It is appropriate to study the internal structure of innovative work activity of science teachers from diametrically opposite groups: Innovators and Laggards group.

We analyzed science teachers' innovative work activities. "Particularly, one distinctive issue for science education is the uniqueness of conducting experiments in the laboratory" (Ng et al., 2019: 2911). Ng et al. (2019) investigate a case promoting science education in innovative ways by the view of experimental pedagogy on the basis of three theories: experiential learning (Kolb, 1984), pedagogical innovation (Walder, 2014), and innovative practice model (Nicolaides, 2012). These theories emphasize the innovative work activities of science teachers. However, they do not examine the internal structure of innovative work activity of science teachers. Our study encourages researchers to look at the application of innovations in science education through an internal structure of innovative work activity of science teachers at different models of experimental pedagogy: experiential learning, pedagogical innovation, and innovative practice model.

Our research has some limitations. The first limitation concerns the study samples: the samples of science teachers in the countries (Italy, Lithuania, Sweden, Norway) varied widely. However, this difference had no statistically significant effect on the final result. We relied on valid and reliable TIMSS 2015 research questions about science teachers' innovative work activities (Table 1). It would be appropriate to conduct research on the innovative work activities of science teachers using other research instruments.

6. Conclusion

The current study has attempted to adapt RDI in science education. According to RDI, innovative work behavior of science teachers manifests itself in the following activities: new ideas exploration, generation, championing, implementation and confirmation.

We analyzed innovative work activities of science teachers on the basis of TIMSS 2015 data from Italy, Lithuania, Sweden, Norway. The highest standardized coefficients were detected analyzing the influence of new ideas generation activity on new ideas championing ability and analyzing the influence of new ideas generation activity on new ideas sharing activity. The direct effect of new idea generating ability on new idea sharing ability is stronger than the indirect effect.

Our study complements a theoretical proposition on how the innovative work activities of teachers are related to the facets of idea generation and implementation covering both the generation and implementation of new ideas.

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