Improving green transport literacy through gamification: A structural equation modeling approach

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Abstract

In this study, the use of gamified workshops is proposed as a suitable tool for teaching knowledge about green transport of goods to anchor climate change engagement in logistics careers. We aim at investigating people's knowledge about green transport using social cognitive career theory (SCCT) as theoretical basis. A questionnaire measures the constructs external barriers, external support, self-efficacy, and vocational interest as well as the newly introduced construct green transport knowledge covered with knowledge questions. The method of structural equation modelling (SEM) is applied to evaluate the path directions and relationship between descriptive statistics, measurement model, structural model evaluation and the four constructs. We found that the four tested hypotheses are significant with varying coefficients. Our sample includes 195 responses from Austria. Additionally, the findings suggest that gamified workshops are effective in promoting green transport knowledge and raising people's vocational interest in transport careers. Further research should evaluate how other educational strategies may be used to further improve knowledge acquisition and long-term effects.

Keywords

climate change engagement, gamified workshops, structural equation modeling, green transport, social cognitive career theory

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1. Introduction

Climate change engagement of organizations represents one of the most critical challenges for the next decades to achieve a decarbonization and the Green Deal goals [1]. Particularly, freight transport requires a greening due to its significant impact on the environment such as CO2 emissions, noise, or other air pollution gases [2]. In comparison to other sectors, such as energy, industry and agriculture, the greenhouse gas emissions of the transport sector have been increasing since 1990 [3]. Furthermore, studies indicate that emissions from the transport sector will double until 2050 [4–6].

An important prerequisite for a greening of the transport sector [7], is the need to strengthen people's knowledge about green transport and thus, motivate them for climate change engagement [8]. The current freight transport system is a result of decisions made by professionals in the past, shaped by their education and experiences. Increasing the awareness of green transport through diverse educational methods has become essential to tackle the harmful effects of freight transport [9, 10]. Gamification is a useful way used in the educational sector to raise awareness, to motivate to develop (new) skills and to change behaviour [11, 12]. According to [13], the behaviour and attitude of individuals towards environmental awareness and climate change engagement can be positively affected by gamification. [14] claim for the use of a greater variety of research methods

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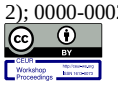

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for the analysis of environments about climate change engagement. Our study addresses this research gap in three major contexts. First, we employ a different method to examine the effects of gamification in workshop environments by using a (1) structural equation model (SEM) to test four hypotheses. Second, we apply a (2) career theory to gamification workshops to evaluate the effectiveness of promoting engagement in green transportation occupations. Finally, we analyse (3) knowledge transfer related to eco-friendly transportation with the goal of improving climate change engagement in the transport sector. Therefore, we created a workshop design with the goal to provide participants with a greater understanding of green transport to enhance climate change engagement and to stimulate an interest in green transport careers. In doing so, we expect to attract people for the transport sector and to encourage them to apply their new gained knowledge of green transport into their daily working routine.

2. Theory and hypotheses

Our hypotheses are grounded by literature on the application of the social cognitive career theory (SCCT) as described by [15], which has been further developed by various studies. This theory aims to explain three interconnected aspects of career development. Firstly, it examines the development of basic academic and career interests. Secondly, it analyses the decision-making processes related to educational and career choices. Finally, it focuses on how individuals attain academic and career success [16–18]. We applied the social cognitive career theory to the field of green transport. Specifically, we utilized the theory's proposition that individuals learn from their past experiences and social factors, and actively shape their career paths through their behavior and support-seeking [19], to assess knowledge about eco-friendly transportation through gamified workshops. This approach is based on previous research that has demonstrated the effectiveness of gamification techniques in stimulating individuals' interest and engagement in environmental issues [20, 21]. Thus, we followed the results of the work done by [21] and [22] and selected the SCCT as the underlying theory for the conducted study.

The initial theory consists of four core constructs: external barriers (EB), external support (ES), self-efficacy (SE), and vocational interest (VI).

H1: External barriers negatively influences self-efficacy.

H2: External support positively influences self-efficacy.

H3: Self-efficacy positively influences vocational interest.

With the intention of more effectively assessing the transfer of green transport knowledge, we adapted the original SCCT model and used green transport knowledge instead of the construct outcome expectation [23]. The theory suggests that individuals with positive outcome expectations are more likely to pursue careers that align with their goals and interests, while those with negative expectations may be hesitant to take risks or pursue new opportunities [19]. Our goal was to investigate the relationship between vocational interest and green transport knowledge by adapting the model and assessing the effectiveness of gamified workshops. We aimed to provide insights into how to anchor climate change engagement in logistics careers through this model adaption. Building on previous research by [24] who tested the SCCT in the context of sustainability career analysis, we adapted the model to analyse the possible effects of knowledge acquisition and career development in the context of green transport. Therefore, we propose:

H4: Vocational interest positively influences green transport knowledge.

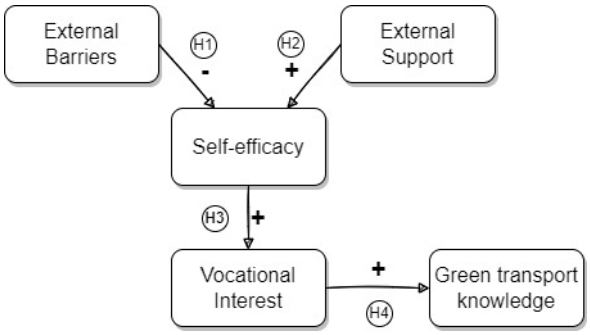

Figure 1: Proposed structural model for explaining the acquisition of green transport knowledge through gamified workshops.

This proposed SCCT model offers a comprehensive approach to assess the transfer of green transport knowledge. The path model in Figure 1 represents the constructs and its relationships based on the SCCT literature [21, 23] summarizing our hypothetical assumptions.

3. Methodological approach

Our research environment are one-day gamified workshops held in Austria with diverse groups of people ranging from students, long-term unemployed people including people of a broad variety of ages and genders. The goal of these workshops is to transfer knowledge about green transport in a gamified way.

3.1. Gamified workshop design

Our workshop concept consisted of several 3.5- to 4-hour sessions using game-based elements to increase participant engagement and interaction. The workshops began with an introductory presentation (1) on the topic, followed by three interactive games. The first game, *"Logistics Job Activity"* (2), was an analogue game without the use of technology. The second game was an interactive quiz played using the online platform *"Kahoot" (3)*. In this game, participants accumulated points and received immediate feedback on their score per question as well as their position on a leaderboard. The third game played in groups was the app Logistify, which used augmented reality as an additional technology and was played on tablets. The workshops aimed to provide students with a comprehensive understanding of decarbonization in transport logistics by integrating both theoretical and practical knowledge. Specifically, the goal was to illustrate how eco-friendly transportation practices can help mitigate climate change and how individuals can incorporate such practices into their daily routines.

We modified the workshop content after each run according to the lessons learned and analyzed the effects of the modifications on knowledge retention, taking into account the moderating effects of gender and age. Workshop instructors remained the same throughout the study to eliminate any confounding influences.

3.2. Survey and participants

A questionnaire was used to evaluate the demographics of the participants, the constructs of the SCCT theory according to [23] and [21] and the construct for green transport knowledge (see Appendix). Green transport knowledge covers eight knowledge questions which deal with content which was learned during the gamified workshop. The questionnaire was completed by the participants after the workshop. A total of 195 participants in 20 workshops completed the questionnaire. All participants were recruited from high school and university programs at various institutions (i.e. vocational schools, higher education institutions, universities). The gamified workshops were conducted between January 2021 and December 2022. The demographic information of our sample about gender, age and educational background in the field of logistics is shown in Table 1.

Table 1
HTMT matrix

variable		count	%
gender	female	127	65.1
	male	68	34.9
age groups	<20	68	34.9
	20-29	51	26.2
	30-39	36	18.5
	40-49	23	11.8
	50-59	16	8.2
	>59	1	0.5
logistics background	yes	53	27.2
	no	142	72.8

3.3. Measurement model and analysis

In our research we want to quantify the constructs (latent variables) drawn from SCCT and test the plausibility of our hypothetical assertions (H1 to H4) about the interrelationships between external barriers, external support, self-efficacy, vocational interest, and green transport knowledge (Figure 1). The multivariate analysis method of SEM is identified as the appropriate tool to fulfil these tasks [25]. We measure the constructs with several items (see Appendix) in a structured questionnaire using Likert-scales with magnitude from 1 (totally disagree) to 7 (totally agree). For data analysis, SmartPLS 4.0, which is based on partial least squares (PLS) modelling, was used. The proposed structural model in Figure 1 has a high exploratory approach. Since the data was not-normal distributed and the aim of this model is to predict a certain behaviour, the PLS based approach to SEM was chosen for this model [25, 26].

The measurement model shown in Figure 2 consists of reflective variables and is assessed by the indicator loadings for item reliability, composite reliability (CR) for internal consistency reliability, average variance extracted (AVE) for convergent reliability and HTMT, as suggested by [27]. If the measurement model assessment is satisfactory, the structural model is assessed using VIF, R^2, statistical significance and relevance of path coefficients [27].

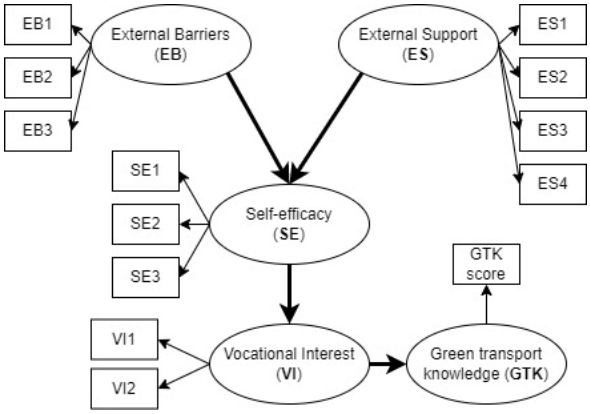

Figure 2: Measurement model

4. Preliminary results

The mentioned literature supports our hypotheses leading to the assumption that knowledge may be acquired or enhanced by the means of gamification. During our further research, we aim to confirm the correlations shown in Figure 1 statistically. Figure 2 exhibits our path model and extends the structural (inner) model in Figure 1 by our measurement (outer) model. We assume that the indicators are manifestations of the underlying construct assuming a reflective measurement model where the indicators are highly correlated and interchangeable [25]. The evaluation of the measurement model shows satisfactory results. The considered thresholds are summarized by [27]. First, the computed item (outer) loadings are above the minimum value of 0.708 (see Appendix). Second, Table 2 shows the results for CR and AVE as reliability measures, which are within the desired thresholds of 0.60 to 0.95 (CR) and above 0.50 (AVE). And third, Table 3 depicts the convergent reliability using HTMT with the values below the threshold of 0.85 to ensure the quality of the measurement model.

Since the quality of the measurement model was ensured, the evaluation of the structural model was conducted. First, collinearity was examined using VIF values. The values of the inner and outer model are close to 3 or lower, which indicate that there is no collinearity issue [27]. Second, the R^2 values of the endogenous constructs are evaluated (shown in Figure 3). Self-efficacy has a value of 0.514 which is interpreted as a moderate explanatory power. Vocational interest shows only weak explanatory power with R^2=0.236 and green transport knowledge (R^2=0.037) no explanatory power according to R^2 measure thresholds [27].

Table 2
Results for Bootstrapping routine

	Composite reliability	AVE
EB	0.724	0.597
ES	0.872	0.715
SE	0.913	0.849
VI	0.915	0.837

Table 3
HTMT matrix

	EB	ES	GTK	SE
ES	0.201			
GTK	0.059	0.051		
SE	0.394	0.758	0.052	
VI	0.174	0.615	0.217	0.538

The investigated path coefficients for H2 and H3 are higher than the suggested minimum value of 0.2 [28] as shown in Table 4. H1 reveals a negative coefficient which confirms our assumption, that external barriers have a negative influence. The coefficient for H4 is slightly below the recommended threshold with 0.193. The p-values for all hypotheses indicate strong significance of the anticipated relationships.

Table 4
Results for Bootstrapping routine

	path	co-efficient	t	p
H1	EB→SE	-0.238	3.949	0.000
H2	ES→SE	0.640	12.462	0.000
H3	SE→VI	0.486	8.107	0.000
H4	VI→GTK	0.193	2.853	0.004

Figure 3 depicts the summary of our SEM results with the structural model, the four path coefficients between the constructs leading to green transport knowledge and R^2 values of the

constructs. H1, H2 and H3 are accepted due to adequate path coefficients and p-values as well as acceptable R^2 values (see Figure 3). Although the p-value of H4 indicates high significance, the path coefficient is low. We accept H4, well aware that the relationship from vocational interest to green transport knowledge need further investigation.

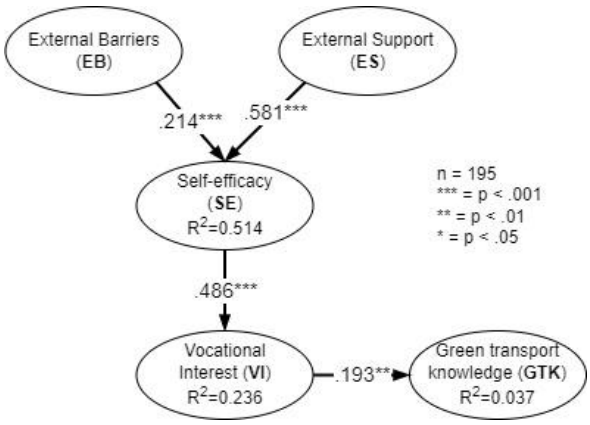

Figure 3: Summarized SEM results.

5. Conclusion and outlook

We contribute to a transformation of the transport sector by imparting green transport knowledge in a gamified way to the forthcoming generation of personnel. This knowledge should encourage people to make green transport decisions in their daily working routine, motivate people for green transport careers and thus, contribute to climate change engagement. We identified SCCT as appropriate grounding theory to investigate career choice processes. This paper contributes to the existing body of gamification research by measuring the knowledge acquisition after a gamified workshop and influencing constructs according to SCCT, enhancing the research on gamification in the context of SCCT towards green transport. While our variables are related to social cognitive career theory, our study emphasizes the unique contribution of gamification to this theoretical framework. Our findings suggest that gamified workshops are an effective means of promoting green transport knowledge and raising people's vocational interest in transport careers.

Given that [14] emphasizes the need for a broader range of research methods to be utilized in investigating gamified environments within the realm of climate change engagement, our study makes a significant contribution in this regard through three distinct avenues. Firstly, we demonstrate that the use of a SEM provides a valuable advantage in analysing complex relationships and facilitates an assessment of the effectiveness of gamified workshops in the context of green transport logistics education. Secondly, we show that the career theory SCCT is an effective method for analysing career choice models in relation to green transport careers. Thirdly, our analysis of the knowledge output pertaining to green transport contributes to filling this research gap by highlighting that gamification is a viable approach for enhancing environmental awareness.

Further investigation might include a variation of the gamified workshop program and multigroup analysis of demographic variables such as gender, type of education and age. A more elaborate longitudinal experimental design such as proposed by [14] with different control groups would help to shed light on the impact, such as the stability of vocational interest and the green transport knowledge.

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7. Appendix

Table 5
Measurement items and their loadings

item	loading	question
EB1	0.797	It is possible that I am treated differently from others in the logistics sector because of my demographic background (e.g. age, gender, origin).
EB2	0.711	I assume that I am subject to discrimination in the logistics sector because of my demographic background (e.g. gender, age, origin).
EB3	0.806	I think that I will have a hard time getting ahead in a job in the logistics sector.
ES1	0.850	I think I have enough knowledge to get a job in the logistics industry
ES2	0.854	I think I have an education that will allow me to enter the logistics industry

ES3 0.871	I think my education prepares me for a job in the logistics industry
ES4 0.806	I think I have enough contacts to help me get into the logistics industry
SE1 0.915	I am sure that I can get a job in the logistics industry.
SE2 0.919	I am able to learn the skills required for a job in the logistics industry
SE3 0.931	I am confident that I could successfully work in the logistics industry
VI1 0.949	I am interested in a job in the logistics industry.
VI2 0.879	I am not interested in entering the logistics industry.
GTK 1.000	Sum of correct answers to the knowledge questions about green transport.

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