RESEARCH ARTICLE

Higher education chemical lab safety interventions: Efficacious or ineffective?

In this paper, we first derive a model from literature providing insights into the influence of different aspects of safety on each other, that is, knowledge, perception, attitude, behavior and its consequences. We called it the "KPABC model". An experiment was furthermore designed and carried out to investigate the impact of laboratory safety interventions with students, and on the different safety aspects of the KPABC model. We finally explain the research results, and based on the findings, we provide recommendations on how to improve safety within higher education chemical labs.

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INTRODUCTION

The perception people have of risks is steered by a variety of factors that determine what risk is considered acceptable, and what risk is deemed unacceptable. Perception is therefore very important, since if one has the mere perception that a (physical and/or theoretical) risk is high, one will consciously or unconsciously take actions to reduce the risk. Hence, influencing the perception is influencing the risk. The perception obviously is partially influenced by knowledge, which can be measured. Other factors influencing perception are beliefs, assumptions, and espoused values, which are not, or much more difficult, to measure.

Furthermore, perception is strongly related with attitude. Risk attitude can be regarded as the chosen state of mind, mental view or disposition with regard to those uncertainties that could have a positive or a negative effect on achieving objectives. Hillson and Murray-Webster (2005) explain that attitudes differ from personal characteristics in that they are situational responses rather than natural preferences or traits, and chosen attitudes may therefore differ depending on a range of different influences. If these influences can be identified and understood, they can be changed and individuals and groups may than pro-actively manage and modify their attitudes. Simply put, a person's risk attitude is his or her chosen response to perception of significant uncertainty.

Different possible attitudes result in differing behaviors, which lead to consequences. All these different measurable concepts mentioned above, can be translated into a model, which we call the 'KPABC-model' (based on Hillson and Murray-Webster, 2005). The learning model is illustrated in Fig. 1.

Remark that an arrow (X → Y) indicates an influence from X toward Y in Fig. 1.

As Hillson and Murray-Webster indicate, although the responses to situations suggest at first sight that situation is the foremost determinant of behavior, in fact it is how the situation is perceived by each person, since a situation that appears hostile to one may seem benign to another. This leads to the important question of what influences behavior when the situation is uncertain. In this case it is essential to know whether uncertainty is perceived as favorable, neutral, unfavorable, or hostile. This reaction to uncertainty is risk attitude. Risk attitudes exist on a spectrum. The same uncertain situation will elicit different preferred attitudes from different individuals, depending on how they perceive the uncertainty. Hence, different people will behave differently to the same situation, as a result of their differing underlying risk attitudes and perceptions.

As indicated above, (safety) knowledge as well as (safety) perceptions and (safety) attitudes are measurable. Kines et al. (2011) define safety climate as "workgroup members' shared perceptions of management and workgroup safety related policies, procedures and practices". Hence, safety climate is determined by measuring the safety perceptions of individuals who belong to a workgroup, with

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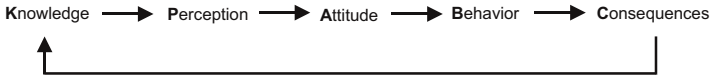

Fig. 1. KPABC model.

respect to safety policies, safety procedures and other safety practices. Measuring the safety perception of a group of people thus leads to an understanding of the *perception* on the 'real' situation (as regards safety) of this group of people – nothing more, nothing less. The safety perception result should thus not be seen as a measurement of reality, nor should it be interpreted on an individual level. James and Jones (1974) mention a study by Campbell et al. (1970) indicating that a 'perceived situation will determine behavior and attitudes in organizations'. Hence, we may conclude that safety attitudes do not coincide with the perceived safety situation (which can be expressed by the safety climate), but that it should be seen as a consequence, as should behavior. There is no general agreement in literature whether safety attitudes should be regarded as a part of safety climate or not, due to a lack of a generally accepted causal model indicating the cause, the content and the consequences of safety climate (Guldenmund, 2000). However, this does not affect the validity of the KPABC-model (see above), since it only concerns a semantic discussion on safety climate.

Remark that Consequences will inform Knowledge moving forward, so that the KPABC model is best depicted as a learning cycle rather than as a linear model.

Holding this KPABC-model in mind, we will investigate and evaluate the short-term effects of three chemical lab safety intervention sessions on safety knowledge, safety perception (safety climate), safety attitude, and safety behavior, in an intervention group in relation to a control group. The study should then provide insights into the short-term effects of safety interventions: do such interventions influence all aspects of the KPABC-model, or only a part of them, and what recommendations can be given based on the results?

METHODOLOGY

Procedure and participants

This study had a longitudinal quasi-experimental design with two measures from the same individuals in the intervention and control group. The present paper focuses on measurement of the effect of the intervention, using a paper-and-pencil questionnaire survey at baseline (at time 1 – indicated in the remainder of the paper as "T1"), in February 2013, prior to the different interventions in the intervention group, 4 (intervention session 1), 9 (intervention session 2) and 10 (intervention session 3) weeks later. The questionnaire survey was repeated for both groups 12 weeks after baseline, in May 2013 (at time 2 – indicated in the remainder of the article as "T2").

Participants of the intervention group consisted of bachelor students in Applied Economic Sciences. 124 students (83 males/41 females) were recruited at baseline (T1). In total, 110 persons (88.7%) remained at T2 (72 males/38 females). The average age of the students was 18.20 years ($SD = .62$). Participants of the control group consisted of 95 bachelor students in Communication Studies (23 males/72 females) at T1 of which 62 persons (65.3%) remained at T2 (13 males/49 females). The average age of the students was 20.79 years ($SD = 2.03$).

Measurements

We developed a short questionnaire to assess students' safety knowledge, safety perceptions, safety attitude and safety behavior. In order to know whether the items of the concepts resemble to the respective (latent) concepts, we performed factor analysis. Details on the factor loadings are provided in Appendix A.

Safety knowledge. Five items measured the respondent's safety knowledge, or his/her estimate of such knowledge. Sample items are "I know how to use a fire extinguisher", "I know where the emergency exits are when I am in a building", and "I know the meaning of the most common symbols of chemical danger". The items were scored along a five-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*. A factor analysis on the five items (principal factor analysis with varimax rotation, PFA) revealed the presence of one factor, with factor loadings ranging from .39 to .70, $R^2 = 39.96$, at T1, and ranging from .50 to .67, $R^2 = 49.35$, at T2. The range in those factor loadings indicated that each item contributed adequately to the concept of safety knowledge. The reliability of the scale was adequate (Cronbach's alpha = .62 and .74 at T1 and T2 respectively).

Safety climate. The safety climate scale measured participants' perception regarding the safety importance within the institution and consists of five items that were scored along a five-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*. Sample items are: "My educational institution provides – on a regular basis – training sessions with regard to our safety" and "My educational institution values the health and safety of the students". Factor loadings (PFA) ranged from .49 to .77, $R^2 = 55.12$, at T1 and from .61 to .87, $R^2 = 66.89$, at T2. The reliability (Cronbach's alpha) of the scale was .79 at T1 and .87 at T2.

Safety attitude. Respondents rated their attitude by means of the following four semantic differential seven-point scales, ranging from 1 to 7: "To follow the safety rules is . . .?" Item 1: *Bad – Good;* Item 2: *Useless – Useful;* Item 3: *Not important – Important;* and Item 4: *Irresponsible – Responsible.* Factor loadings (PFA) ranged from .51 to .82, $R^2 = 60.88$, at T1 and from .52 to .91, $R^2 = 68.48$ at T2. The reliability (Cronbach's alpha) of the scale was .77 at T1 and .83 at T2.

Safety behavior. To measure students' safety behavior, respondents were asked to rate six self-constructed questions on a five-point Likert scale ranging from 1 = *rarely or none of the times* to 5 = *most or all of the time*. Sample items are: "I use the pedestrian crossing when crossing the road",