Are game elements fueling learners' motivation via positive affect?

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Abstract. The use of game elements in learning tasks is often motivated by the aim of utilizing their motivational capabilities. Even if game elements do not directly affect cognitive learning outcomes, they can keep learners engaged and support long-term loyalties. In this contribution, we present an investigation of the effect of game elements with a specific focus on affective and motivational aspects. In particular, we report a value-added online experiment, comparing a game-based version with a non-game-based version of an association learning task. In total, 61 participants completed the experiment. While we find comparable cognitive learning outcomes, we find medium and large differences in affective and motivational outcomes. Game elements are associated with an increase in positive affect and seem especially suited to serve learners' need for competence. The game-based task was further perceived significantly more attractive and stimulating. Mediation models revealed that the increased cognitive cost introduced by game elements was effectively balanced by their benefits regarding motivation. The latter was partially mediated by changes in positive affect. In sum, the net cognitive outcome was the same for both tasks, but learners in the game-based condition were more positively affected, more motivated and felt more competent. Implications and future research directions are discussed.

Keywords: game elements, association learning, cognition, motivation, affect.

1 Introduction and theoretical background

The use of games in educational contexts is often based on the aim to leverage their capabilities in capturing and holding people's attention and in fostering sustained engagement and motivation [1]. While previous reviews yielded mixed results regarding outcomes of game-based learning, recent meta-analyses support their effectiveness concerning cognitive and motivational outcomes for learning in school [2] and higher education [3]. Meta-analyses have further shown that already the inclusion of specific, separable game features in digital tasks (gamification) can enhance engagement [4] and motivation [5]. While game-based learning and gamification are certain-

ly distinct approaches, the motivational capabilities of their common feature of game elements have been corroborated for both game-related pedagogies [6].

However, the exact mechanisms by which game elements exert their effects during learning are far from being fully elaborated [7]. The Integrated Cognitive Affective Model of Learning with Multimedia (ICALM) [8] provides a theoretical framework which can shed light on how cognitive and motivational aspects may be related. This contribution attempts to clarify further the relations between game design features, cognition, affect, and motivation during learning within the framework provided by ICALM.

Theoretical background. A crucial point in the ICALM model [8] is that cognitive processes are inseparably intertwined with affective processes induced by the learning environment. If attributable to a specific source these affective processes are subjectively experienced as emotions, whereas otherwise they may persist unattributed as mood. Affect that involves appraisal is subjectively experienced in the form of interest or motivation. In any of these forms, affect influences selection and organization processes in working memory and is finally integrated also into emotionally laden schemas stored via long-term memory.

The important point for the present work is that affective dynamics provide a link between design features of the learning environment and motivational learning outcomes [7]. In other words, design features may induce affect, which may enhance motivation. Research in the framework of self-determination theory [1] has shown that high levels of motivation, particularly intrinsic need satisfaction for autonomy, competence, and relatedness, are characteristics of high-quality learning. Hence, the affective dynamics initialized by game elements may fuel learners' motivation which in turn may enhance cognitive outcomes.

However, according to ICALM [8], affective processes also pose additional demands on cognitive resources. According to multimedia learning research [9], this may finally lead to a zero net effect on cognitive outcomes, as found in earlier studies [10-12], via the mutual cancelation of motivational benefits with cognitive demands.

Present study. The present study aimed to test these theoretical considerations empirically by utilizing the well-established value-added research paradigm [13]. To do so, we aimed for clarification of the following hypotheses.

Informed by our previous study focusing on behavioral engagement during a similar task [10], we did not expect a net difference between task versions regarding cognitive learning outcomes. However, we hypothesized that the task versions differ regarding affective or motivational outcomes. We further hypothesized that the motivational benefits of game elements counter-balance their higher cognitive processing demands and are partially mediated by affective outcomes.

By testing these hypotheses, we aimed to answer the following research questions. Can specific, separable game features influence cognitive, affective, or motivational learning outcomes in an association learning task? Are motivational effects accompanied or mediated by affective effects as suggested by the ICALM model? Are game elements associated with (partially) antagonistic motivational and cognitive effects?

2 Methods

Participants. In total, 61 participants (44 female, 15 male, 2 diverse) completed the study. The participants' age ranged from 18 to 64 years (M = 27.56, Mdn = 24, SD = 11.54, MAD = 4.45; all in units of years). Most of the participants were students (51 of 61). Psychology students were compensated for study participation by course credit. All study participants provided informed consent. The study was approved by the Ethics Committee of the University of Graz.

Study design. We conducted a value-added research experiment (see Fig. 1). Participants were randomly assigned to one of two experimental conditions. The two experimental conditions comprised two learning task versions differing solely in the use of specific, separable game elements, described below.

Before (pre-task survey) and after (post-task survey) the task, participants were administered questionnaires regarding affective and motivational constructs (besides socio-demographic data). Details on the used questionnaires are given below. Both surveys were implemented with LimeSurvey. After completing data acquisition, appropriate measures of effect size (see below) were computed for all outcome variables regarding differences between the two experimental conditions.

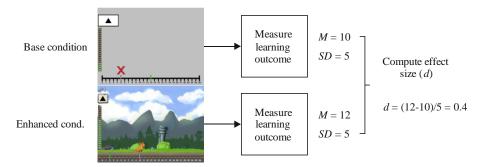


Fig. 1. Study design illustrating condition comparison using fictional descriptive statistics.

Learning task. The goal of the participants was to memorize associations between 20 symbols and numbers over five consecutive levels. For each symbol, participants had to indicate a number, distributed spatially on a visual number line ranging from 0 to 26 (see Fig. 1) by using the left and right arrow keys of the keyboard and pressing the spacebar to confirm their choice. Each symbol corresponded exactly to one location along the number line specified by its respective number. These associations between symbols and numbers were fixed over the entire task, but initially unknown to the participants. Participants had 20 s for each symbol to select a number and confirm their choice. After each response (or after expiration of the maximum response time of 20 s) participants would receive corrective feedback (see Fig. 1). A green vertical bar would indicate the correct position/number associated with the currently presented symbol and some visual aesthetic, which differed between game and non-game task versions (see below), would indicate if the choice was correct.

The differences between the non-game and game task versions comprised a narrative, visual aesthetics, and a virtual incentive system. The narrative in the game version of the task consisted of a dog walking in a forest searching for bones hidden by an enemy. The only hint the dog would have for the location of the bones was a set of symbols, each associated with a certain position in the ground. By memorizing the associations between symbols and numbers, the participants could assist the dog in finding the hidden bones. In the game version of the task, the cursor's movement was accompanied by a walking animation of the dog. The placement of the cursor (by pressing the spacebar) would initiate a digging animation. Correct positioning resulted in the dog wagging its tail and the bone count increasing by one (incentive system). In the case that the position was incorrect, the dog would cry instead, and the correct position was shown (i.e., corrective feedback). In the non-game version, a green check mark and a red X-symbol would indicate correct and incorrect responses, respectively. The non-game version would also lack all described visual aesthetics. Instead, a constant, empty, grey background was presented (see Fig. 1).

Learning outcome measures. Regarding learning outcome measures, we discern between cognitive, affective, and motivational outcome measures. Regarding cognitive outcomes, we discern further between learning efficacy (i.e., did participants learn over the course of the task?) and learning efficiency (i.e., how fast did participants learn?). Efficacy was measured by the number of correct responses for each task level. Efficiency was measured by fitting an exponential learning curve [14] to the series of those numbers for each participant:

$$N_{\text{corr},i}(L) = N_{\text{max}}\{1 - \exp[-C_i(L-1)]\}$$
 (1)

In Eq. (1), $N_{\text{corr},i}(L)$ denotes the number of correct responses of the *i*-th participant at task level L, $N_{\text{max}} = 20$, and the coefficient C_i denotes the rate constant indicating the learning efficiency of the *i*-th participant.

Affective and motivational outcomes were assessed using self-report questionnaires. Positive and negative affect was assessed before and after the learning task using the positive and negative affect schedule [15]. PANAS provides 20 adjectives describing feelings and emotions like "excited" or "distressed". Participants are asked to indicate the intensity with which they were experiencing these emotions on a 5point scale ranging from "not at all" to "very much". Ten adjectives are associated with each positive and negative affect. Regarding affect, we compared the two conditions regarding the change in affect from before to after the learning task and testing condition equivalence before the learning task.

To assess motivational outcomes, we used the two subcomponents *interest* (items like "The activity in the learning task was fun") and *perceived competence* (items like "I am satisfied with my performance in the learning task") of the short scale to measure intrinsic motivation developed by Wilde et al. [16]. The two subcomponents comprise 3 items each. All items were answered on a 5-point rating scale ranging from "does not apply at all" to "applies completely". The subscales *perceived choice* and *pressure/tension* were not included since the mechanics of the learning task did not allow for customization of the learning activity.

Motivational outcomes were complemented by the *attractivity* and *stimulation* subscales of the user experience questionnaire [17]. Both subscales consist of several items, each presenting two opposing adjectives, forming the endpoints of a 7-point rating scale, on which participants indicate their experience of the task. In particular, *attractivity* aims to assess how enjoyable, good, pleasing, pleasant, attractive, and friendly a product (or task) is perceived. *Stimulation* aims to assess how valuable, exciting, interesting, and motivating a product (or task) is perceived. Regarding their face validity, the two subscales are thus closely related to qualities associated with (intrinsic) motivation. All motivational outcomes were assessed after the learning task.

Internal consistency of all scales was satisfactory, $\alpha > 0.87$. All scales were administered in German.

Data analysis. Count data were analyzed regarding statistical significance using Fisher's exact test. Differences between means were statistically analyzed using robust methods based on trimmed means (Yuen's test, robust ANOVA) provided by the WRS2 package [18] with trimming kept at 0.2, if assumptions for parametric tests (ttest, parametric ANOVA) were not met (normality, homogeneity of variances and covariances). Trimmed means are denoted by the symbol M_t . For reporting effect sizes in the case of robust comparisons, we refer to the effect size δ_t suggested by Algina et al. [19] as a robust alternative for Cohen's d. Associations between variables were assessed using percentage bend correlations ρ_{pb} (i.e., a robust correlational measure [18]). Mediation models were based on robust regression using M-estimators [20]. Indirect effects were tested using Zu and Yuan's robust approach [21]. 95% confidence intervals (CIs) are reported directly following the respective quantity in squared brackets. All statistical analyses were conducted using R [22].

3 Results

Condition equivalence. Of 61 participants, 33 and 28 participants ended up in the non-game and game condition, respectively. The conditions were equivalent regarding gender distribution, p > 0.999, and regarding counts of student and non-student participants, p = 0.488. In the non-game condition, the participants' age ranged from 18 to 64 years (Mdn = 23, MAD = 4.45), while in the game condition, it ranged from 19 to 61 years (Mdn = 24.5, MAD = 5.19), yielding also no significant difference, $Y_t = 0.30$, p = 0.775.

The conditions were also equivalent regarding participant attrition during the learning task, p = 0.526. In the non-game condition, 49 persons started the task and 33 completed it. In the game condition, 47 started the task and 28 completed it. The conditions were further equivalent regarding positive affect before the task (non-game: M = 3.02, SD = 0.80; game: M = 2.90, SD = 0.72), t(58.76) = 0.61, p = 0.547. The conditions were also equivalent regarding negative affect before the task (non-game: Mdn = 3.10, MAD = 0.89; game: Mdn = 3.00, MAD = 0.74), $Y_t = 0.73$, p = 0.476.

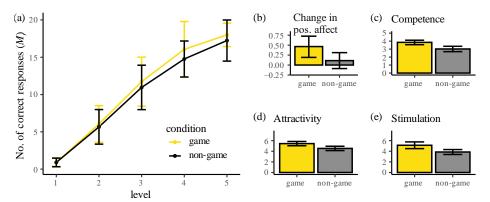


Fig. 2. (Trimmed) means and their 95% CIs for some cognitive, affective and motivational outcome measures.

Cognitive outcomes. Learning efficacy was not significantly different between conditions at any task level. In particular, a robust two-way between-within subjects ANOVA yielded a significant main effect of level, $Q_{level}(3, 28.19) = 167.76$, p < 0.001, yet no significant main effect of condition, $Q_{condition}(1, 33.87) = 0.30$, p = 0.590, and also no significant interaction, $Q_{level,condition}(3, 28.19) = 0.52$, p = 0.673. The trimmed means and their 95% CIs are provided for each task level in Fig. 2(a).

Learning efficiency was also not significantly different between the game ($M_t = 0.53$ [0.40, 0.65]) and the non-game ($M_t = 0.46$ [0.28, 0.63]) conditions, $\Delta M_t = 0.07$ [-0.13, 0.26], $Y_t = 0.48$, p = 0.479, $\delta_t = 0.18$ [-0.32, 0.62].

Affective and motivational outcomes. The results for the comparisons between task conditions regarding affective and motivational outcomes are summarized in Table 1. We obtained a significantly larger increase in positive affect from pre- to post-task in the game than in the non-game condition, yielding a medium effect. The means of the change in positive affect for the two conditions and their 95% CIs are depicted in Fig. 2(b). Negative affect decreased from pre- to post-task in the non-game condition, while it increased slightly in the game condition; however, the difference between conditions was not significant, but was again close to a medium effect. We obtained no notable difference in reported interest. Perceived competence was significantly higher in the game than in the non-game condition, see also Fig. 2(c), accounting for a large effect. Also, the task's attractivity and stimulation by the task were rated significantly higher in the game than in the non-game condition, see Fig. 2(d&e), accounting in both cases for large effects.

Table 1. Results of comparisons between groups concerning the considered affective and motivational outcomes.

Outcome measure	Test statistics	Effect size
Change in pos. affect	t(53.78) = 2.01, p = 0.049	d = 0.52 [-0.01, 1.06]
Change in neg. affect	$Y_t = 1.67, p = 0.090$	$\delta_t = 0.48 \ [-0.11, 1.06]$
Interest	$Y_t = 0.56, p = 0.538$	$\delta_t = 0.16 [-0.46, 0.57]$
Competence	t(58.42) = 3.52, p < 0.001	d = 0.89 [0.37, 1.44]
Attractivity	$Y_t = 3.00, p = 0.003$	$\delta_t = 0.82 \ [0.39, 1.33]$
Stimulation	$Y_t = 3.17, p < 0.001$	$\delta_t = 0.87 \ [0.24, 1.69]$

Correlational analyses. Changes from pre- to post-task in negative and positive affect were not significantly correlated with each other (p > 0.05). Neither was the change in negative affect significantly correlated with any of the motivational variables (p > 0.05). In contrast, the change in positive effect was significantly correlated with all motivational variables (p < 0.01), yielding medium associations with $0.34 < \rho_{pb} < 0.44$. Interest was significantly correlated with the other motivational variables (p < 0.05), yielding also medium associations with $0.29 < \rho_{pb} < 0.33$. Perceived competence, attractivity, and stimulation were highly correlated among each other (p < 0.001), yielding large associations with $0.78 < \rho_{pb} < 0.86$, indicating that any of them may be utilized as a proxy for (intrinsic) motivation.

The effect of task condition (non-game or game) on learning efficiency was mediated by attractivity, see Table 2. While we obtained a significant, small indirect effect, both direct and total effects of condition on efficiency were insignificant, indicating that game elements yielded not much of an effect on cognitive outcomes anyway. Replacing attractivity with any of the other two motivational measures yielded very similar, but slightly smaller effects.

The effect of task condition on attractivity was further partially mediated by the change in positive affect, see Table 3. The small significant indirect pathway somewhat reduced the condition's total effect on attractivity, while the dominant contribution was still retained in the direct pathway.

Table 2. Results obtained for the robust mediation model with attractivity mediating the effect of condition (non-game or game) on learning efficiency.

Type	Effect	β	p
Component	Condition \rightarrow Attractivity	0.73 [0.31, 1.15]	< 0.001
	Attractivity → Efficiency	0.26 [0.04, 0.48]	0.020
Indirect	Cond. \rightarrow Attr. \rightarrow Eff.	0.24 [0.03, 0.55]	0.021
Direct	Condition → Efficiency	-0.12 [-0.56, 0.31]	0.572
Total	Condition \rightarrow Efficiency	0.09 [-0.33, 0.53]	0.659

Table 3. Results obtained for the robust mediation model with change in positive affect (ΔPA) mediating the effect of game elements on attractivity.

Type	Effect	β	р
Component	Condition $\rightarrow \Delta PA$	0.46 [-0.06, 0.98]	0.080
	$\Delta PA \rightarrow Attractivity$	0.32 [0.11, 0.53]	0.004
Indirect	Cond. $\rightarrow \Delta PA \rightarrow Attr.$	0.17 [0.01, 0.42]	0.038
Direct	Condition → Attractivity	0.58 [0.16, 0.99]	0.008
Total	Condition → Attractivity	0.73 [0.31, 1.15]	< 0.001

4 Discussion

Altogether, we find that specific, separable game features influenced cognitive, affective, and motivational aspects in our association learning task. In particular, they affected the development of positive affect rather than negative affect, which agrees with an earlier finding of the capability of game-based learning to elicit especially positive (epistemic) emotions [23]. Our correlational analyses indicated that the two assessed dimensions of user experience [17] in the form of attractivity and stimulation may be utilized as proxies for (intrinsic) motivation. Doing so in subsequent mediation analyses revealed that motivation appears at least partially mediated by these changes in positive affect. Finally, and in line with earlier studies [9,10], we found evidence that game elements are associated with antagonistic effects on cognitive outcomes, i.e., their slightly higher demand on cognitive resources appeared effectively balanced by their motivational benefits.

It should be noted that the task did not represent a very favorable context for game elements taking effect at all. In earlier studies on fraction estimation [12,24], basically the same game elements were intrinsically integrated into the learning task. Choosing the correct location along the number line required to estimate a given fraction accurately and why the information about the location was given in form of a fraction in the first place was part of the game narrative. In the implementation of the task in the present work, however, the associations between symbols and locations along a numbered line were neither tied to the provided visual aesthetics nor to the background narrative. Neither was there any further meaning to the incentive system apart from providing feedback on learning progress. Overall, the intrinsic integration of game elements can be regarded as relatively low in the present case. Yet the more astonishing are the effects of those game features regarding affective and motivational outcomes (also considering the small sample size). The coherence principle developed within multimedia learning research would advocate avoiding any additional, unnecessary information [25], which would certainly apply to our game elements in the present context from a mere cognitive perspective. In line with a more integrative perspective [9], we arrive, however, at a very different conclusion. Cognitively, the additional costs introduced by game elements are effectively balanced by their indirect effects along the affect-motivation-cognition pathway in line with the ICALM model [8]. However, regarding their affective and motivational effects, they come

with substantial benefits. We cannot but to conclude that, apart from implementation cost, there remains little to no good reason not to implement learning tasks in a game-or playful form.

Limitations and outlook. Our correlational analysis cannot confirm causal relations. Causation also implies temporal directionality and exclusion of alternative causation pathways including, for instance, fundamental sensory aspects like structural properties of design elements, perceptual salience of stimuli or figure-ground effects. Regarding temporal directionality, our results cannot confirm that attractive design elements lead to a positive, affective response, which, in turn, leads to enhanced motivation upon appraisal, resulting eventually in a self-amplifying, feed-forward cascade of engaging in an in-itself rewarding activity. The latter might indeed be a foundation of the persistent activity players can show when immersed in a well-designed game, which, according to SDT [1], is characteristic of high-quality learning. However, illuminating this requires further research digging deeper into the microstructure of learning processes. One way (among others) to approach this would be to temporally resolve the development of affective dynamics by, for instance, leveraging the potential of multimodal assessment of physiological correlates besides longitudinal, repeated sampling of situational interest, motivation and emotion.

References

- Ryan, R. M., Rigby, C. S.: Motivational foundations of game-based learning. In: Plass, J. L., Mayer, R. E., Homer, B. D. (eds.) Handbook of game-based learning, pp. 153–176. MIT Press, London (2020).
- Barz, N., Benick, M., Dörrenbächer-Ulrich, L., Perels, F.: The effect of digital game-based learning interventions on cognitive, metacognitive, and affective-motivational learning outcomes in school: A meta-analysis. Review of Educational Research, 003465432311677 (2023).
- Hu, Y., Gallagher, T., Wouters, P., Van Der Schaaf, M., Kester, L.: Game-based learning has good chemistry with chemistry education: A three-level meta-analysis. Journal of Research in Science Teaching 59, 1499–1543 (2022).
- Looyestyn, J., Kernot, J., Boshoff, K., Ryan, J., Edney, S., Maher, C.: Does gamification increase engagement with online programs? A systematic review. PLoS ONE 12(3), e0173403 (2017).
- 5. Sailer, M., Homner, L: The gamification of learning: a meta-analysis. Educational Psychology Review 32, 77–112 (2020).
- Zhang, Q., Yu, Z.: Meta-analysis on investigating and comparing the effects on learning achievement and motivation for gamification and game-based learning. Education Research International, 1519880 (2022).
- 7. Loderer, K., Pekrun, R., Plass, J. L.: Emotional foundations of game-based learning. In: Plass, J. L., Mayer, R. E., Homer, B. D. (eds.) Handbook of game-based learning, pp. 111–151. MIT Press, London (2020).
- 8. Plass, J. L., Kaplan, U.: Emotional design in digital media for learning. In: Tettegah, S. Y., Gartmeier, M. (eds.) Emotions, Technology, Design, and Learning, pp. 131–161. Academic Press, Cambridge (2016).

- 9. Park, B., Flowerday, T., Brünken, R.: Cognitive and affective effects of seductive details in multimedia learning. Computers in Human Behavior 44, 267–278 (2015).
- 10. Huber, S. E., Cortez, R., Lindstedt, A., Kiili, K., Ninaus, M.: Game elements enhance engagement and mitigate attrition in online learning tasks. *Under review*.
- 11. Bernecker, K., Ninaus, M.: No pain, no gain? Investigating motivational mechanisms of game elements in cognitive tasks. Computers in Human Behavior 114, 106542 (2021).
- Ninaus, M., Cortez, R., Hazin, I., Kiili, K., Wortha, S. M., Klein, E., Weiss, E. M., Moeller, K.: The added value of game elements: better training performance but comparable learning gains. Educational Technology, Research and Development (2023).
- 13. Mayer, R. E.: Cognitive foundations of game-based learning. In: Plass, J. L., Mayer, R. E., Homer, B. D. (eds.) Handbook of game-based learning, pp. 83–110. MIT Press, London (2020).
- Leibowitz, N., Baum, B., Enden, G., Karniel, A.: The exponential learning equation as a function of successful trials results in sigmoid performance. Journal of Mathematical Psychology 54, 338–340 (2013).
- Breyer, B., Bluemke, M.: Deutsche Version der Positive and Negative Affect Schedule PANAS (GESIS Panel). Zusammenstellung sozialwissenschaftlicher Items und Skalen (2016).
- Wilde, M., Bätz, K., Kovaleva, A., Urhahne, D.: Überprüfung einer Kurzskala intrinsicher Motivation (KIM). Zeitschrift für Didaktik der Naturwissenschaften 15, 31–45 (2009).
- Schrepp, M., Hinderks, A., Thomaschewski, J.: Die UX KPI Wunsch und Wirklichkeit.
 In: Hess, S., Fischer, H. (eds.) Mensch und Computer 2017 Usability Professionals, pp. 117–125. Gesellschaft für Informatik e.V., Regensburg (2017).
- Mair, P., Wilcox, R. R.: Robust Statistical Methods in R Using the WRS2 Package. Behavior Research Methods 52, 464–488 (2020).
- Algina, J., Keselman, H. J., Penfield, R.D.: An alternative to Cohen's standardized mean difference effect size: a robust parameter and confidence interval in the two independent groups case. Psychological Methods 10(3), 317–28 (2005).
- Venables, W. N., Ripley, B. D.: Modern Applied Statistics with S. 4th edn. Springer, New York (2002).
- 21. Zu, J., Yuan, K.: Local influence and robust procedures for mediation analysis. Multivariate Behavioral Research 45(1), 1–44 (2010).
- 22. R Core Team: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna (2022). https://www.R-project.org
- 23. Kiili, K., Siuko, J., Cloude, E., Dindar, M.: Motivation and emotions in a health literacy game: Insights from co-occurrence network analysis. In: Kiili, K., Antti, K., de Rosa, F., Dindar, M., Kickmeier-Rust, M., Bellotti, F. (eds.) Games and Learning Alliance. GALA 2022, LNCS, vol. 13647, pp. 149–159. Springer, Cham (2022).
- 24. Kiili, K., Moeller, K., Ninaus, M.: Evaluating the effectiveness of a game-based rational number training—In-game metrics as learning indicators. Computers & Education 120, 13–28 (2018).
- Mayer, R. E. (ed.): The Cambridge handbook of multimedia learning. Cambridge University Press, New York (2005).