Building a heatmap rubric to assess student's meaningful learning based on the Interaction Equivalency Theorem

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In the evolving landscape of education, understanding how different modalities of course delivery impact student learning is crucial. Anderson's Interaction Equivalency Theorem (2003a) (IET) provides a guideline for designing effective interactions in distance learning. Anderson's two theses in his theorem are:

- *"Thesis 1. Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student–student; student–content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience."*
- *"Thesis 2. High levels of more than one of these three modes will likely provide a more satisfying educational experience, although these experiences may not be as cost- or time effective as less interactive learning sequences."*

While Anderson's Theorem was based on the distance education system in its modeling it can be extended to various modalities such as hybrid and traditional learning. The Interaction Equivalency Theorem (IET), proposed by Garrison (2017), emphasizes that a balance of three types of interaction (student-content, student-student, and student-teacher) can lead to meaningful learning. In this article, we propose the development of a ***heatmap rubric*** *based on a meta-analysis of a large body of literature and established best practices, aimed at assessing meaningful learning through a comparative analysis of interactions across diverse course delivery modalities.*

Understanding the Interaction Equivalency Theorem

The IET posits that meaningful learning occurs when a learner actively engages with content, peers, and instructors (Miyazoe, M., & Anderson, T., 2010). Here's a breakdown of the three types of interaction according to Moore (1989):

1. Student-Content Interaction: This involves students engaging with course materials, such as readings, videos, and assignments.

2. Student-Student Interaction: This encompasses collaboration, discussion, and peer feedback among students, fostering a community of learners.
3. Student-Teacher Interaction: This includes feedback, guidance, and support from instructors, which can greatly enhance the learning experience.

By assessing these interactions, educators can gain insights into how effectively a course delivery method facilitates meaningful learning. However, the IET lacks delineating meaningful learning at the intersection of students' interaction type and course delivery modality. We suggest developing a heatmap rubric, which will characterize different levels of this intersection, and enable the identification of the highest level of meaningful learning.

Designing the Heatmap Rubric

The term heatmap was first trademarked in the early 1990s, when software designer Cormac Kinney created a tool to graphically display real-time financial market information (Jurkonytė, 2023). The practice we now call heatmaps is thought to have originated in the 19th century, where manual gray-scale shading was used to depict data patterns in matrices and tables.

The heatmap rubric here will serve as a visual representation of the levels of meaningful learning in a course. Here's how to create one:

Step 1: Define Learning Outcomes

Establish clear, measurable learning outcomes that reflect meaningful learning. These outcomes should align with the course objectives and provide a foundation for assessing meaningful learning.

Step 2: Identify Course Delivery Modalities
Different course delivery modalities may include:

- Face-to-Face: Traditional classroom settings.
- Blended Learning: A mix of face-to-face and online instruction.
- Fully Online: Courses delivered entirely through digital platforms.

Step 3: Develop Interaction Metrics
Create specific metrics to measure each type of interaction. Possible metrics could include:

- Frequency of engagement (e.g., number of posts in a discussion forum).
- Quality of interactions (e.g., depth of responses).
- Diversity of interactions (e.g., variety of sources used in student-content engagement).

Step 4: Create the Heatmap Framework
Design a heatmap table that includes:
- Horizontal row: Course delivery modalities (face-to-face, blended, fully online).
- Vertical row: Types of interactions (student-content, student-student, student-teacher).

Each cell in the table will represent the intensity or effectiveness of interaction for that modality and type. Use color coding to indicate levels of engagement ranging from low (e.g., red) to high (e.g., green).

Step 5: Collect Data
Gather data through surveys, learning analytics, and observational methods.

This may include:
- Student feedback on their interactions.
- Analysis of discussion posts, assignments, and assessments.
- Instructor observations of engagement levels.

Step 6: Populate the Heatmap
Input the collected data into the heatmap. Each cell should reflect the observed levels of interaction, indicating how well each modality supports meaningful learning.

Step 7: Analyze and Reflect
Once populated, analyze the heatmap to identify trends. For example, you might find that:

- Face-to-Face: High levels of student-teacher interaction but lower student-student interaction.
- Blended Learning: A balanced approach, with moderate levels of all three interactions.
- Fully Online: High student-content interaction, but lower student-teacher engagement.

Reflect on these insights to inform future course design and delivery.

Implications for Course Design

By utilizing a heatmap rubric, educators can tailor their courses to enhance meaningful learning. If a particular modality shows low interaction levels, adjustments can be made, such as:

- Incorporating more collaborative activities in online settings to boost student-student interaction.
- Increasing opportunities for feedback and engagement from instructors in blended courses.

Generating Heatmap Rubric

Based on a meta-analysis of 200 peer-reviewed articles (refined to 187) research studies were classified according to the combination of course modality and interaction type that most effectively promotes meaningful learning (Anderson, 2003; Moore, 1989). This classification produced nine unique combinations**:** *face-to-face* × *student-content* (Rossi et al. 2021; Buhl-Wiggers et al. 2023; Lewohl et al. 2023; Photopoulos et al. 2022; Li et al. 2023; Scager et al. 2016; Dubinsky et al. 2024; Xu et al. 2023; Mebert 2020; Ipinnaiye et al. 2024; Ramos-Vallecillo et al. 2024; and Carnegie Mellon University 2021), *face-to-face* × *student-student* (Bailey et al. 2018; Bennett et al. 2014; Bernard et al. 2009; Borokhovski et al. 2012; Bruffee 1999; Chickering and Gamson 1987; Chim et al. 2024; Dzemidzic Kristiansen et al. 2019; Gillies 2023; Guiller et al. 2008; Herrmann and Kims 2013; Huang et al. 2023; Johnson and Johnson 1999; King 1998; Lewohl et al. 2023; Means et al. 2013; Mesghina et al. 2024; Ocker and Yaverbaum 1999; Peterson et al. 2023; Ransom et al. 2022; Scager et al. 2016; Slavin 1995; Tenenbaum et al. 2019; Topping 2005; Van Ryzin et al. 2019; Webb 1989; Webb 1994; Yang et al. 2023; and Zhang et al. 2022), *face-to-face* × *student-instructor* (Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C., 2009;

Buhl-Wiggers, J., et al., 2023; Chickering, A. W., & Gamson, Z. F., 1987; Cornelius-White, J., 2007; Garrison, D. R., Anderson, T., & Archer, W., 2000; Hamre, B. K., Pianta, R. C., & others, 2013; Hattie, J., 2009; Lewohl, J. M., et al., 2023; Li, L., 2021; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K., 2013; Ong, S. G. T., et al., 2023; Pennings, H. J. M., et al., 2020; Photopoulos, P., 2022; Pianta, R. C., and colleagues, various years; Roorda, D. L., Koomen, H. M., Spilt, J. L., & Oort, F. J., 2011; Tao, Y., 2024; Zhang, Q., 2024), *blended* × *student-content* (Akai, G. 2022; Al Mamun, M. A. 2022; Arnett, T. 2016; Bondarenko, O., Pakhomova, O., & Lewoniewski, W. 2020; Bonk, C. J., & Graham, C. R. 2006; Child Education Through Animation 2014; Columbia Center for Teaching and Learning 2018; De Bruijn-Smolders, M. 2024; Doubet, K., & Carbaugh, E. M. 2020; Farhat, A. 2025; Garrison, D. R., Anderson, T., & Archer, W. 2000; Gitinabard, N., Xue, L., Lynch, C. F., Heckman, S., & Barnes, T. 2017; Islam, M. B., Ahmed, A., Islam, M. K., & Shamsuddin, A. K. 2014; Kettlehake, K. 2025; Li, L. 2022; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. 2013; Rabadi, S. 2025; Seaton, D. T., & Thoms, B. D. 2016; Smith, D. P. 2022; Tayebinik, M., & Puteh, M. 2015; Ye, Y., Zhang, G., Si, H., Xu, L., Hu, S., Li, Y., Zhang, X., Hu, K., & Ye, F. 2023; Zhang, L. 2025), *blended* × *student-student* (Ajibade, O. 2016; Armellini, A. 2021; Avcı, H. 2017; Bekele, A., Melese, W., & Sime, T. 2025; Borup, J. 2013; Bruffee, K. 1999; Challob, A. I. 2016; De Bruijn-Smolders, M. 2024; De Bruijn-Smolders, M. 2024; Garrison, D., Anderson, T., & Archer, W. 2000; Han, F., & Ellis, R. A. 2021; Istenič, A. 2024; Islam, M. K. 2022; Jong, J. P. 2016; Kintu, M. J., Zhu, C., & Kagambe, E. 2017; Lacaste, A. V. 2022; Li, J. 2023; Li, R. 2025; Mahgana, A. J. 2025; Malsakpak, M. H. 2024; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. 2013; Meulenbroeks, R. 2020; Mohammadi, M. 2025; Moodley, K. 2023; Pham, A. T. 2025; Platonova, R. I. 2022; Platonova, R. I., Armellini, A., & colleagues 2021; Pokhrel, S., Rasheed, A., et al. 2021; Ruijuan, L. 2023; Sareen, S. 2024; Scager, K. 2016; Sharma, D. 2022; So, H. J. 2008; Tang, J. T. 2025; Wang, P. 2024; Yang, X. 2023; Younas, M. 2025; Yu, Q. 2025; ResearchGate / cooperative study 2012–2013; ResearchGate / Ajibade 2016), *blended* × *student-instructor* (Alammary, A., Sheard, J., Carbone, A., 2014; Arbaugh, J. B., 2014; Borup, J., Graham, C. R., Drysdale, J. S., 2014; Borup, J., West, R. E., Thomas, R., Graham, C. R., 2020; Brundage, M. J., Malespina, A., Singh, C., 2023; Chen, P. D., Lambert, A. D., Guidry, K. R., 2010; Chickering, A. W., Gamson, Z. F., 1987; De Bruijn-Smolders, M., 2024; Farhat, A., 2025; Garrison, D. R., Anderson, T., Archer, W., 2000; Hsu, L., Ching, Y., 2013; Lee, R. A., 2011; Li, L., et al., 2022; Martin, F., Bolliger, D. U., 2018; Miller, J. B., 2013; Ong, S. G. T., et al., 2023; Prokopetz, R. Z., 2021; Rabadi, S., 2025; Rovai, A. P., Jordan, H. M., 2004; Schmid, R. F., 2023; Su, F., 2023; Vaughan, N., 2007; Woo, Y., Reeves, T. C., 2007; Zafonte, M., Parks-Stamm, E. J., 2016; Zafonte, M., Parks-Stamm, E. J., 2016; Bernard, R. M., et al., 2009; Vaughan, N., 2007; Arbaugh, J. B., 2014), *online* × *student-content* (Al Mamun, M. A., 2022; Baber, H., 2020; Bond, M., Bedenlier, S., & Zawacki-Richter, O., 2020; Dikbaş-Torun, A., 2020; Garrison, D. R., & Cleveland-Innes, M., 2005; Garrison, D. R., Anderson, T., & Archer, W., 2001; Joksimović, S., et al., 2019; Kidder, L. H., 2015; Koernig, S. K., 2003; Kuo, Y. F., et al., 2013; Lee, J., 2010; Meyer, K. A., 2014; Moore, M. G., 1989; Murray, M., 2013; Orcutt, D., & Dringus, L. P., 2017; Pham, T. T., et al., 2019; Reisetter, M., LaPointe, D., & Korcuska, J., 2007; Sweetman, D. S., 2020; Xiao, Y., et al., 2024; Zhao, Y., et al., 2023; Zhao, Y., et al., 2023), *online* × *student-student* (Ascough, R. S., 2007; Blackmon, S. J., & Major, C. H., 2012; Collier, A., & McDonald, J., 2019; Gao, L., 2020; Garrison, D. R., Anderson, T., & Archer, W., 2001; Johnson, D. W., Johnson, R. T., & Smith, K. A., 1991; Kearsley, G., & Moore, M. G., 1996; Liu, M., & Hwang, G. J., 2010; Moore, M. G., 1989; Ramsden, P., 2003; Rasheed, R. A., Khan, S. U., & Dufresne, R., 2020; Rovai, A. P., 2002; Swan, K., & Shih, L. F., 2005; Vygotsky, L. S., 1978; Wang, M., & Chen, L., 2019), and *online* × *student-instructor* (Arbaugh, J. B. 2008; Dixson, M. D. 2015; Leem, B. H. 2023; Li, X. 2022; Mullen, G. E. 2006; Ong, S. G. T. 2023; Su, C. Y. 2021).

Articles were tallied within each combination, and the results were visualized using a 3 × 3 heatmap grid illustrated in table 1 below. Each cell of the grid represents a specific modality–interaction pairing, with the vertical axis denoting instructional modality (face-to-face, blended, online) and the horizontal axis denoting interaction type (student-content, student-student, student-instructor). The numerical value in each cell indicates the number of studies supporting meaningful learning within that combination. The color gradient reflects the magnitude of meaningful learning – darker shades correspond to a greater number of studies and thus stronger evidence of meaningful learning within that instructional context.

		Type of Interaction		
		Student–Content	Student–Student	Student–Instructor
Course Modality	Face-to-face	**12**	**29**	**17**
	Blended	**22**	**37**	**27**
	Online	**21**	**15**	**7**

Table 1. Results of heatmap grid pairing course modality & type of interaction

Results Discussion

The heatmap grid shows that areas of high intensity are concentrated around the blended learning modalities, indicating higher levels of meaningful learning across all interaction types – a consistent conclusion of meta-analyses. Face-to-face learning remains strongest for *relational and collaborative engagement* but less efficient for content interaction alone. Online learning supports *autonomy and content mastery* but often yields lower *social and instructor presence* unless meticulously designed.

It is notable to mention the above classification echoes a robust body of scholarship and empirical synthesis, drawing on both foundational frameworks and meta-analyses, including Chickering and Gamson (1987), Moore (1989), Garrison, Anderson, and Archer (2000), Bernard et al. (2009, 2014), Means et al. (2013), and Borup et al. (2020), which collectively highlight the relative impact of various interaction modalities across in-person, blended, and online learning contexts.

Conclusion

A heatmap rubric offers a valuable tool for assessing the interactions that drive meaningful learning, grounded in the Interaction Equivalency Theorem. By examining the course modality and type of student interaction combinations, this meta-analysis aimed to identify patterns in which instructional approaches and interaction types most strongly support meaningful learning outcomes. The results provide a framework for understanding how different learning environments and interaction dynamics contribute to student engagement, knowledge construction, and overall satisfaction with the learning experience.

By understanding the dynamics between course delivery modalities and interaction types, educators can create more effective learning environments that cater to diverse student needs, ultimately enhancing the educational experience. Embracing this approach will ensure that all learners can thrive, regardless of the modality through which they engage with course content.

Considerations for future research

The next phase of this research will proceed in two stages. First, the heatmap analysis will be refined to categorize each mode of student interaction according to the topical concepts proposed by Rodriguez and Armellini (2014). These concepts may include: (1) level of engagement with course activities, (2) depth of reflection on course topics, (3) extent of instructor support in content comprehension, (4) sharing of valuable learning experiences with peers, and (5) overall satisfaction with the learning experience. The heatmap will then be expanded to provide a more detailed and comprehensive depiction of the three-way interactions among these factors.

The second stage will involve follow-up empirical confirmatory research to further examine the heatmap rubric's content, design, and implementation. Data will be collected on the rubric's specific components as it is applied across a variety of classroom settings and teaching modalities, enabling the establishment of its validity and reliability.

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