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ADAPTING THE BEHAVIOR OF VIRTUAL CHARACTERS IN EDUCATIONAL VIDEO GAMES

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Abstract. Virtual players, also known as non-playable characters (NPCs), are utilized in educational video games to create an engaging gameplay experience that leads to improved learning outcomes and enhanced skills and competencies. To foster motivation and engagement among real game players, such NPCs often exhibit dynamically adapted behavior tailored to the player's specific attitudes, outcomes, and emotions. This literature review examines existing approaches and techniques for user-centered adaptation of NPC behavior in educational video games. To create more effective, plausible, and motivating NPCs, the authors seek to identify the dimensions of NPC behavior that convey emotional state, as well as the player characteristics modeled to support user-centric adaptation of NPC behavior. Next, the paper outlines the techniques implied for the implementation and validation of such adaptation, followed by modern trends and research challenges in NPC behavior adaptation, in the epoch of a massive invasion of AI. The findings promise to help specialists design, implement, and validate more plausible and intriguing NPCs, with enhanced abilities to motivate and engage real players of educational video games.

Keywords: Video games; NPC; Adaptation; Behavior

1. Introduction

Serious, or so-called 'applied', digital games are designed and developed for vocational training, advertising, politics, defense, and various other purposes (Laamarti et al., 2014). Most of them are focused on learning and teaching; hence, they are educational video games (Zhonggen, 2019). The predominant genres of such games are puzzles, strategy, simulation, and role-playing games (RPGs) (Robinson et al., 2021), which are primarily designed for the single-player paradigm.

To create an engaging, motivating gameplay experience in single-player video games, including educational tasks to enhance learning outcomes and skill development, virtual players (also known as non-playable characters,

or NPCs) are used (Ravyse et al., 2017). Starting as virtual heroes with very simple avatars and behavior based on embedded small dialogue trees (Collins et al., 2016), NPCs have become increasingly complex and interactive. Strategy games such as "Civilization" and "SimCity" rely on NPCs to provide real players with context-oriented feedback, help, and additional challenges (Lux & Budke, 2020). In the last two decades, educational games have begun to integrate NPCs and leverage intelligent software agents, in some cases with specific mental attitudes, such as belief-desire-intention agents (Raguraman & Raju, 2024). The modern development of artificial intelligence (AI) has advanced NPC behavior and facilitated adaptation to real players' actions, behavior, and outcomes. In popular educational video games like "Minecraft" and "Kahoot! ", NPCs serve as virtual assistants and tutors, helping real players master knowledge and skills across various didactic domains (Garcia & Puchades, 2022).

The present study focuses on approaches and techniques for user-centered adaptation of the behavior of virtual (non-player) characters in video games for educational purposes. For creating more effective, plausible, and motivating NPCs, the authors pose the following research questions about the design and implementation of dynamic tailoring of their behavior:

- RQ1: What are the dimensions (i.e., features) of the NPCs' behavior used to express their emotional state?
- RQ2: How are the player characteristics modeled for player-centric NPC behavior adaptation, and which techniques are implied for its implementation and validation?
- RQ3: What are the modern trends and research challenges in NPC behavior adaptation, in the epoch of a massive invasion of AI?

Answering these research questions is based on a literature review of studies conducted in the last 25 years. The findings will help the authors design, implement, and validate more plausible and intriguing NPCs, with enhanced abilities to motivate and engage real players of educational games.

2. Methodology

The survey applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to conduct a transparent, systematic quantitative review of publications in the research

area. The search strategy included defining the search query, selecting the databases to search, and the selection process (as explained below). The search query was as follows:

("digital game*" OR "computer game*" OR "video game*" OR "serious game*" OR "mobile game*") AND (education* OR learning OR teaching) AND (personali* OR adapt* OR customi* OR tailor*) AND (NPC OR "virtual character*" OR "virtual hero*" OR "virtual player*")

The most common scientific databases were investigated using this search query: Scopus (the largest abstract database with broad coverage), Web of Science (the highest-quality peer-reviewed database), and Google Scholar (focused on a wide range of publications, including theses and technical reports). The software tool "Publish or Perish" was used to retrieve the search results from Google Scholar.

Fig. 1 shows the stages of the PRISMA methodology for systematic reviews, which were applied as follows:

1. Using the search query addressing the customization of NPCs in digital games for educational purposes, the authors found 72 scientific English publications in Scopus, 36 in the Web of Science database, and 645 in Google Scholar (journal articles, conference papers, books, and book chapters), i.e., 753 in total, for the period 2000 – 2025.

2. The authors removed 35 duplicates, which resulted in a raw dataset of 718 items.

3. The following inclusion criteria are applied to choose relevant studies: (1) focus on educational video games; (2) detailed descriptions of relevant approaches and methods for implementation of NPCs in games; (3) journal articles, conference papers, books, and book chapters; (4) articles in English.

4. The exclusion criteria were: (1) articles unrelated to educational games; (2) papers lacking an extensive description of NPC behavior; (3) articles not related to our research questions. As a result, 614 irrelevant publications were removed through manual review because they were out of context with the research questions, leaving a cleaned dataset of 104 eligible publications.

5. The sorting-by-citation process resulted in 44 cited publications. To them were added 3 publications from 2024 and 2025 because they could be beneficial to the research area, but have not yet been cited. All documents

dated before 2024 and without citations were excluded, considering they do not impact the research area.

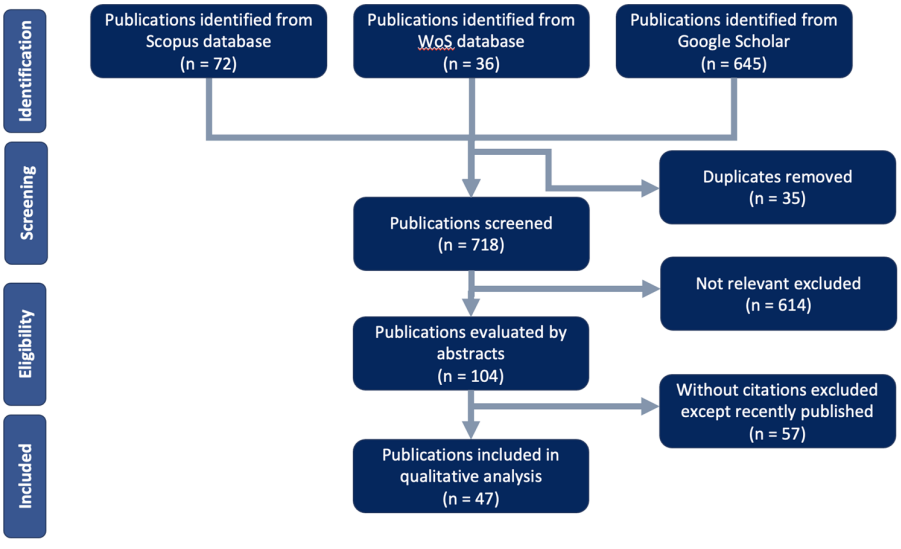

Figure 1. Stages of PRISMA methodology for systematic reviews

3. Background

3.1. Virtual characters in video games

Virtual characters, i.e., non-player characters, have been a central part of video game design since the first video games. The behavior of these first NPCs was entirely pre-determined and very limited. Two primary methods were traditionally used to simulate intelligent behavior in NPCs: finite state machines (FSMs) (Haryanto & Haryanto, 2011) and behavior trees (BTs) (Marcotte & Hamilton, 2017). FSMs date back to the earliest days of digital gaming in the 60s of the last century and provide a relatively simple yet rigid structure for NPCs' behavior. In FSMs, the characters switch among a limited set of predefined states based on specific conditions. The advantage of FSMs is that they are easy to implement, but, as a downside, they become increasingly difficult to manage as the number of states grows. The behavior tree method was introduced to enable more modular, hierarchical behavior modeling and to address these limitations. Both FSMs and BTs are

considered outdated, yet they remain widely used in commercial games to create NPCs. Nonetheless, with the growing complexity of games and higher player expectations, the limitations of these static approaches have become obvious in their ability to deliver realism and adaptiveness in NPC behavior.

Game developers nowadays are overcoming these limitations by integrating artificial intelligence and machine learning (ML) techniques into NPC design (Raguraman & Raju, 2024), such as supervised, unsupervised, and semi-supervised learning. Different learning paradigms enable NPCs to learn from data rather than relying on predefined rules, thereby enabling adaptive behavior. Another technique – deep learning, a subset of ML, uses multi-layered neural networks to allow NPCs to interpret complex data and make abstract decisions.

Large language models (LLMs) are an example of an AI technique that enables the generation of human-like dialogue and improves interaction with NPCs (Huber et al., 2024). Reinforcement learning (RL) is also gaining popularity, enabling NPCs to adapt through trial and error in response to player actions and changing game environments, using algorithms such as proximal policy optimization (PPO) or deep Q-networks (DQN) (Shao et al., 2019). Early RL applications focused primarily on training player agents to play the game. The successful results from these applications motivated researchers to extend RL techniques to NPC behavior.

These advancements in AI and ML integration show promising possibilities for virtual characters to contribute to more personalized and effective gameplay experiences by learning and adapting (Du, 2025).

3.2. Roles of NPC in educational video games

NPCs have long served as essential components in video games, traditionally helping with presenting the narrative or offering gameplay assistance. In the context of educational video games, NPCs are increasingly used as intelligent agents that support diverse learning processes. Recent advancements in artificial intelligence and machine learning have led to improvements in NPCs, which are now interactive, adaptive agents capable of supporting a wide range of educational goals.

In this context, three leading NPC roles have emerged as especially valuable in education: tutor, tutee, and peer, as presented in Fig. 2. (Huyen,

2024) As tutors or virtual mentors/advisors, NPCs offer expert guidance in areas where human expertise may not always be available – such as in medical or technical training. The NPC tutors can provide specialized feedback and mentorship, ensuring that learners receive timely and accurate support. The pedagogical focus here includes expert guidance, scaffolding, and individualized support to advance domain knowledge skills, by using several approaches:

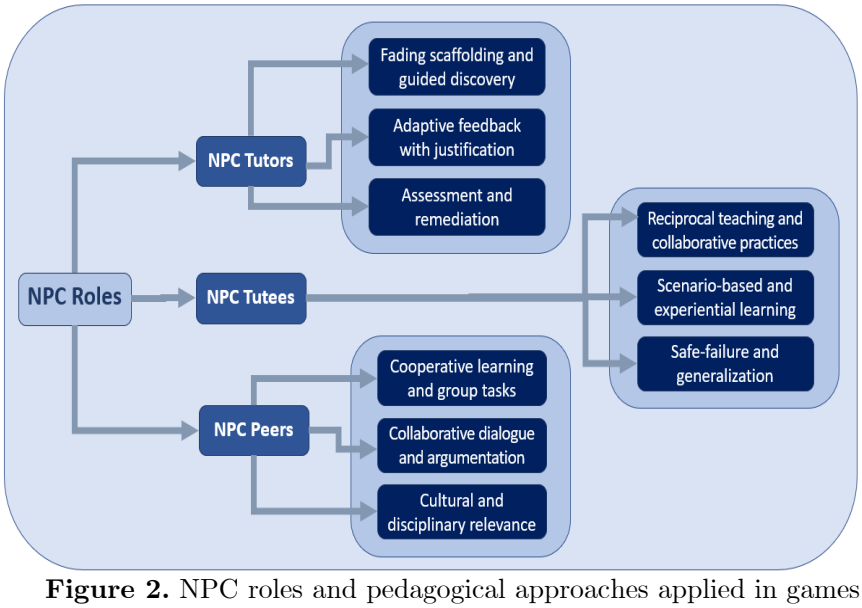

Figure 2. NPC roles and pedagogical approaches applied in games

1. Fading scaffolding and guided discovery – start with problem solving; explicit demonstrations, or strategic questions that lead learners to self-correct their reasoning; then gradually reduce guidance as the learner gains competence.

2. Adaptive feedback with justification – timely, specific feedback that not only states correctness but explains why and how to improve, by directing learners to relevant in-game resources; adjust its difficulty, hints, and pacing based on learner performance and prior knowledge.

3. Assessment and remediation – use brief formative checks to gauge understanding and offer targeted remediation paths, e.g., short quizzes with corrective explanations.

As NPC tutees, the virtual characters serve as virtual students. This is especially helpful for such learners, who are pre-service teachers or professionals in training. The NPC tutees or students assist them in practicing their skills in instruction, mentoring, and classroom management within a safe, repeatable environment. This is particularly beneficial when real-world teaching opportunities are scarce. NPC tutees may collaborate with real players to fulfill specific tasks or otherwise compete with them as opponents. (Punch & Toomey, 2023) The pedagogical focus relies on practice, reflection, and social learning from the learner's actions, often in a safe, repeatable environment, leading to better long-term engagement and motivation of learners:

1. Reciprocal teaching and collaborative practices – here, the learner may guide the NPC through tasks, who then replicates these tasks under feedback, thus reinforcing the didactic content through teaching.

2. Scenario-based and experiential learning – the learner observes consequences in authentic, context-rich situations, evoking reflective prompts and reflections, e.g., the NPC is a trainee who makes decisions in a simulated classroom or lab, aligned to the learner's objectives.

3. Safe-failure and generalization – with tasks that allow trial-and-error without real risks, by learning from mistakes with reversible outcomes; often in new but related contexts to promote generalization.

Finally, the role of NPC peers is to function as virtual classmates. This helps to create collaborative dialogue and enhances problem-solving. When real users are unavailable, NPC peers can simulate social interactions, enabling learners to experience meaningful group learning and community building. (Hwang & Chien, 2022) NPC peers have as a pedagogical focus collaborative learning, social negotiation, and collective problem-solving, by:

1. Cooperative learning and group tasks – promote interdependence, where learners work with or against NPC peers to achieve shared goals (e.g., within a joint project or shared task spaces).

2. Collaborative dialogue and argumentation – by reasoned discussion with NPC with constructive critique to reach multiple viewpoints and build a common understanding, fostering motivation and communication skills.

3. Cultural and disciplinary relevance – NPC should be tailored to fit the subject matter and learner demographics (through translation and localization), providing transparent feedback, accessibility, and inclusivity.

The NPC roles of tutors, tutees, and peers collectively expand the educational capacity of virtual environments, transforming NPCs from static entities into dynamic partners in the learning journey. Generally, NPC tutors focus on accuracy and reasoning, tutees' duties concern practice quality and progression, while peers concentrate on collaboration and communication. A recent study (Agrati, 2023) revealed that the perceived usefulness of these three fundamental NPC roles varies, with 38% for NPC tutors, 29% for NPC peers, and 21% for NPC tutees.

4. User-centered adaptation of NPC behavior

4.1. Dynamic tailoring of features of NPC behavior

To be more effective, plausible, and motivating for the real player, NPCs in educational video games should dynamically tailor their behavior. Various dimensions (i.e., features) of the NPCs' behavior express their current emotional state, which is ultimately influenced by perception, motivation, cognition, memory, and learning (Lim et al., 2012). These behavioral features could be dynamically adapted to learner needs, as follows:

- Facial expressions – grimaces, color of the skin, saccades, eye gaze, and other means of facial expression of emotions and feelings (Reale et al., 2011);
- Voice tone – players appreciate when NPCs react naturally and appropriately to their questions rather than using any predetermined dialogue trees, by responding differently based on tone or volume (both kept in the conversational memory) (Zargham et al., 2025);
- Body language – includes posture, head pose, gesture, and others; predictions about real player characteristics are used to animate the NPC (Dobre, 2023) via pantomiming, gestures, etc. (Šinković, 2024);

- NPC interaction (verbal/speech or non-verbal) – often with an integration of a conversational AI within Non-Player Characters (NPCs) in video games (Nagarkar, 2024). Moderating speech interaction with NPCs in single-player games can increase immersion, engagement, and entertainment (Zargham et al., 2025). Motion in virtual environments can trigger Speech interaction with an NPC (Yin & Xiao, 2024);
- Decision logic – if NPCs can "dynamically react to player actions and pro-actively make decisions in reasonable and realistic ways" (Lim et al., 2012), they would demonstrate a more intelligent behavior, whereupon they resolve on their own what, how, and when to do.

On the other hand, the NPC behavior may reflect a cognitive adaptation tailored to the intellectual content and pedagogical strategy. Such a cognitive adaptation might consist of adjustments to task complexity, scaffolding (level of support provided), sequencing (order of concept presentation), feedback type (corrective, elaborative, or metacognitive), pacing (speed of content progression), and demonstration of the thinking process. Machine learning algorithms promise more effective, player-centric adaptation of NPCs' behavior based on specific features (dimensions) of models of real players/learners, thereby enhancing players' immersion, motivation, and engagement in educational video games (Kishore & Lalitha, 2025).

4.2. Player characteristics used for NPC behavior adaptation

The tailoring of NPC behavior in video games might be based on changes in game mechanics, dynamics, and aesthetics (Kim, 2015), game environment (such as Internet throughput, screen resolution, text-to-speech settings, etc.), other NPCs' behavior, and the individual game player (learner). The last type of tailoring, known as player-centric adaptation, requires specific player modeling (Hooshyar et al., 2019).

Hare and Tang (2022) outline four basic approaches to player modeling that exploit the domains of knowledge, skill levels, emotion, and player attitude. The approaches make use of various adaptation methods ranging from rule-based systems and fuzzy logic to supervised machine learning, and are oriented to specific adaptation targets such as educational/training

adaptation, alert/recommendation systems, dynamic difficulty adjustment (DDA), and emotional support.

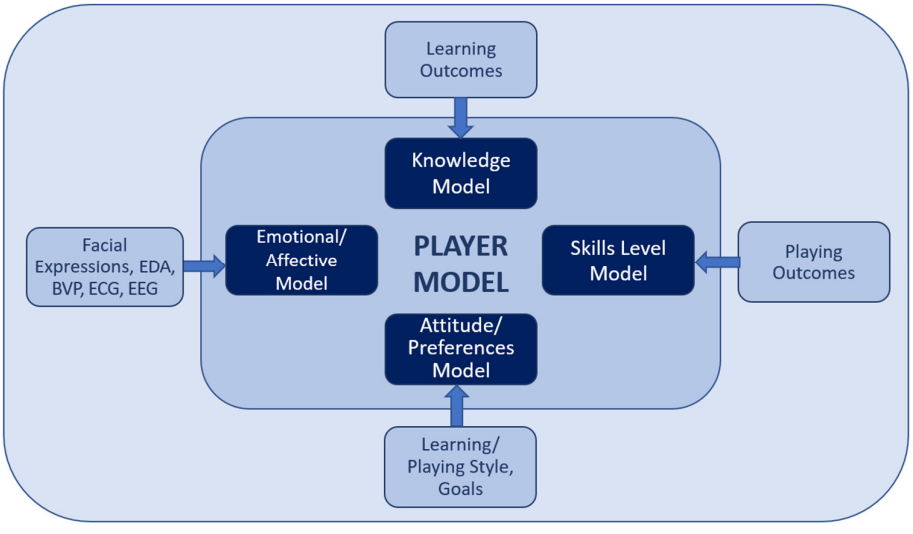

Figure 3. Approaches for player modeling and implementation

Fig. 3 presents the player modeling of knowledge, skill levels, emotion (affect), and attitude (preferences), as summarized in Hare & Tang (2022), together with the specific types of characteristics used for their evaluation, recognition, or prediction. While the models of player knowledge and skill level rely on the outcomes shown by the player in terms of learning and game playing, the attitude model represents the player's preferences based on the initial goals set by the player before starting the game, and the learning or playing style evaluated by self-reports (Veenman et al., 2003) or individual gameplay (Bontchev & Georgieva, 2018). On the other hand, the emotional (i.e., affective) model recognizes the emotional state of the individual by analysis of facial expressions (Li & Deng, 2020) or by psychophysiological measurements of electrodermal activity (EDA), blood-volume pulse (BVP), electrocardiograms (ECG), and electroencephalograms (EEG) (Baig & Kavakli, 2019). EDA, BVP, ECG, or EEG can be applied for evaluation (e.g., by linear regression) or recognition (e.g., by classification) of the player's emotional state; learning or playing styles can

be used for prediction of the player's preferences, while learning and playing outcomes can participate in the evaluation of cognitive and skill-based metrics of the player model.

4.3. Mechanisms for dynamic adaptation of NPC behavior

The mechanisms for dynamic adaptation in educational video games can be applied to tailor gameplay, educational content, interfaces, and non-player character behavior (Aydin et al., 2023). The user-centric adaptation might tailor them to players' knowledge, skill levels, emotions (affect), and attitudes (preferences), as shown in Fig. 3. The emotional state can be recognized using video stream with facial expressions, audio stream with tone expressions, or/and psychophysiological data, as shown in Fig. 4. On the other hand, the player's attitude can be presented as a set of static characteristics, such as goals and learning or playing style, evaluated using self-report data.

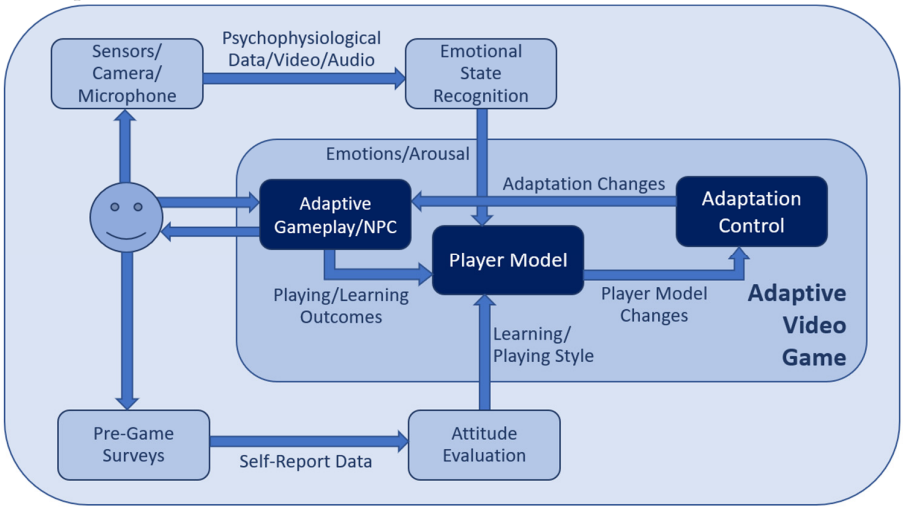

Figure 4. Adaptive feedback loop

Finally, playing and learning outcomes can be tracked throughout the playing session by logging gameplay metrics, didactic results, and interactions with NPCs. All these three inputs are registered within the player model and communicated to the adaptation control module.

Eventually, changes in player metrics could lead to changes in the adapted gameplay and/or NPCs. Popular methods for building decision systems in the control module include Bayesian networks, artificial neural networks, fuzzy logic, deep learning, item response theory, long short-term memory (LSTM), convolutional neural network (CNN), LLM, natural language processing (NLP), and various classifiers. (Aydin et al., 2023) A mapping of the NPC's role (tutor/teacher, tutee/learner, and peer/partner) to the type of behavioral adaptation (verbal, nonverbal, and cognitive), the appropriate AI method, and its key advantage, is available in an online document (see Note 1) and serves as a conceptual framework for adapting NPC behavior that is practically applicable to educational game developers and researchers.

Thus, changes in the chosen gameplay or NPC behavior are based on registered/recognized/evaluated changes in specific player characteristics. The decision logic embedded in the adaptation control module is responsible for controlling these changes. Regarding providing feedback to the real player, it can be implemented implicitly (without informing the player about the change) or explicitly. On the other hand, adaptations to tailored gameplay or NPCs can apply positive, negative, or combined feedback. (Terzieva, 2019)

4.4. Assessing the effect of dynamic adaptation of NPC behavior

Because of the complex nature of digital game environments, researchers require mixed-method evaluations to assess quantitative and qualitative data from different sources. There are two main aspects of the evaluation activities: the software quality of the game environment and the game's effectiveness in achieving the learning outcomes. (Law et al., 2008)

Using Likert-scale questionnaires is a popular method for gathering data to assess the effects of game adaptation. The player is presented with the questionnaire after playing the game (or watching a gameplay video) without the adaptation, and then again after playing the game with the adaptation. The order in which the questionnaires are performed can also be reversed based on a random factor. (Tjokrosetio & Chowanda, 2021) Additionally, a post-interview can be conducted to collect more data. (Lindberg & Laine, 2018)

Questionnaires provide a subjective view of the player's experience of the game, whereas automated log files can collect objective data of the player's behavior in response to the game adaptation. Log files can contain, for example, data on task completion time, the NPC's adaptation time and type, and the player's attention. They can be used to identify correlations between NPC adaptation and player performance. (Law & Sun, 2012)

5. Discussion

Through a literature review of studies conducted from 2000 to 2025, this research analyzed approaches and techniques for player-centered tailoring of the behavior of virtual (non-player) characters in educational video games. Answering the three research questions stated in the article's introduction appears crucial for the successful and effective design, implementation, and practical validation of more plausible and intriguing NPCs with enhanced abilities to motivate and engage players in such video games. The dimensions (features) of the NPCs' behavior, which express their current emotional state, are influenced by the processes of perception, motivation, cognition, memorization, and learning; hence, they were divided into several groups: facial expressions, voice tone, body language, NPC interaction, and decision logic (RQ1). These player characteristics are applied to player-centric adaptation of NPC behavior by modeling four types of concepts: skill level, knowledge, emotional state, and attitude, each of which uses various techniques, implementation, and validation (RQ2). Regarding the current trends and research challenges in NPC behavior adaptation, in the epoch of a massive invasion of AI (RQ3), the study found numerous open research areas where interest can be focused, and further studies can be conducted. Modern trends and research challenges in the dynamic, user-centric adaptation of NPC behavior in the epoch of the massive invasion of generative AI are outlined in an online document (see Note 1). They include personalization based on the player's learning style, culture, and performance; real-time recognition and response to emotion and motivation; and long-term strategies for player engagement. (Terzieva et al., 2022)

The current study was performed under the following limitations:

(1) The authors conducted research over the last 25 years;

(2) All the publications included in the study were in English;

(3) Only journal articles, conference papers, and technical reports were included.

Regarding the quality assessment and evaluation of study bias in the identified articles, the authors found that many NPC customization studies are quasi-experimental. Such studies analyze how different NPC tailoring options affect player experience, engagement, or satisfaction without randomly assigning players to experimental and control groups. Therefore, they have lower internal validity due to the increased risk of bias, and confounding factors can make it harder to draw definitive causal conclusions. On the other hand, some domain-specific quality dimensions of NPC customization research were addressed, namely:

- NPC design quality, including clearly defined role, a clear definition of adaptation mechanism (rule-based, ML, RL, hybrid), adaptation triggers (performance, emotion, or eye tracking), and subject of adaptation (dialogue, behavior, emotion, appearance, etc.); NPC behavior validated before the study (e.g., through pilot testing or expert review);
- Quality of the educational game, including a clear definition of learning objectives, alignment between NPC behavior and learning objectives, and didactic content validated by subject matter experts;
- Outcome measurement quality, including the administration of both pre-test and post-test, engagement and user experience measured with validated scales and instruments, and reporting the statistical significance and effect size;
- Learner sample quality, including adequate sample size, description of participant characteristics (many studies do not report prior knowledge and gaming experience), and description of informed consent and ethical approval.

The present review has practical implications and potential for future empirical validation. The identified research issues and trends in modern tailoring of NPC behavior may serve as a practical guideline for game designers and developers and, conversely, help researchers outline directions for future work. They can help create a taxonomy of NPCs used in educational video games, which would be useful for selecting the specific

features most important for a player-centric adaptation to enhance both the playing and learning processes.

6. Conclusion

Virtual characters have been an integral part of video games for decades and have also found a place in educational video games, serving as tutors, tutees, and peers. Adapting these NPCs' behavior can support learning by creating a more motivating and immersive game environment. In the current study, we have identified that multiple features of the NPCs can be adapted, for example, facial expressions, tone of voice, body language, verbal and nonverbal interactions, and decision logic. The authors investigated the feasibility of implementing user-centric adaptation for adjusting NPC behavior based on the player's knowledge, skill level, emotions (affect), and attitudes (preferences). A player model is proposed in which player inputs are registered and communicated to the adaptation control module, thereby producing changes in the NPC's behavior. The use of questionnaires and automated log files is suggested for evaluating and validating the adaptation.

Taking advantage of the findings presented above, the authors plan several tasks to be conducted in their future studies:

- to select a set of NPC features appropriate for the implementation of adapted behavior in terms of both effectiveness and efficacy;
- to design an approach/algorithm for adaptive NPC behavior addressing motivation and engagement of the real player, with appropriate use of machine learning methods;
- to implement the approach for adaptive NPC behavior in real educational games and to validate it through practical experiments;

Finally, an analysis of the results from gaming sessions with educational video games featuring adaptive NPCs will allow us to propose enhancements to the approach and reveal its implications for game designers and GBL practitioners.

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NOTES

1. Behavior adaptation of NPC in educational video games: https://motivate-bg.online/pdf/NPC-behavior-trends.pdf

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