

INTERACTIVE DATA VISUALIZATION FOR FINANCIAL LITERACY EDUCATION: TECHNICAL PRINCIPLES, LEARNING APPLICATIONS, CHALLENGES, AND FUTURE DIRECTIONS

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Abstract: Financial literacy requires learners to reason about quantities that change across time, interact under constraints, and remain uncertain. Compound growth, debt amortization, cash-flow trade-offs, diversification, and retirement adequacy are therefore difficult to teach through definitions and isolated calculations alone. Interactive data visualization can make these relationships inspectable by connecting financial models with visual encoding, parameter manipulation, comparison, explanation, and feedback. This paper reviews the technical and instructional principles of interactive visualization for financial literacy education, including financial-model validity, graphical perception, interaction design, visualization literacy, cognitive load, uncertainty communication, and data storytelling. Applications include compound interest, budgeting and debt, risk–return and diversification, retirement planning, and learner-facing dashboards. The review argues that visual polish and interface activity are not learning mechanisms by themselves. Educational value depends on alignment among the target decision, model assumptions, representation, guided action, feedback, and transfer assessment. Major challenges include distortion, hidden assumptions, false precision, cognitive overload, uneven numeracy and graph literacy, accessibility barriers, privacy risks, commercial steering, and the substitution of clicks for evidence of learning. A model-aligned synthesis framework is outlined to connect financial questions, validated models, visual encoding, learner actions, diagnostic feedback, and independent assessment. Future systems should prioritize uncertainty-aware scenarios, transparent adaptation, multimodal accessibility, longitudinal evaluation, and reproducible benchmarks. Interactive visualization is most defensible as a structured environment for inquiry and explanation, not as a graphical shortcut to financial competence.

Keywords: Financial literacy; Interactive data visualization; Financial education; Visualization literacy; Uncertainty visualization

1 INTRODUCTION

Financial literacy is more than familiarity with financial terms. It includes the capacity to interpret information, calculate consequences, compare alternatives, recognize uncertainty, and act under constraints. These capabilities matter because choices concerning saving, borrowing, insurance, investment, and retirement accumulate over long periods. Research links financial literacy to important economic outcomes while treating knowledge, education, and behavior as distinct constructs [1]. A meta-analysis of randomized financial-education interventions found positive average effects on knowledge and downstream behavior, although effects still depend on content, timing, population, and measurement [2].

Many core concepts are relational and dynamic. Compound interest links principal, rate, frequency, and time; loan repayment separates interest from principal; diversification links weights, variance, and correlation; and retirement planning connects present contributions with uncertain future needs. A formula may represent one relationship exactly without showing how several inputs move together. Interactive visualization can connect these models with observable consequences.

An interactive visualization maps data to graphical marks and adds operations such as selecting, filtering, comparing, changing parameters, or requesting details. Neither graphics nor interaction guarantees comprehension. An accurate chart may be misread, a calculator may invite unstructured clicking, and a persuasive narrative may hide alternative assumptions. The relevant question is which representation and interaction help a particular learner perform a defined financial reasoning task.

The evidence base is encouraging but heterogeneous. A systematic review of 37 studies identifies charts, dashboards, simulations, visual analytics, and feedback tools, together with substantial variation in topics, learners, technologies, and evaluation designs [3]. Direct studies reject a simple hierarchy in which more graphics or interaction always produce more learning. A large online experiment supports short-term benefits from appropriately designed visual explanations [4]. In compound-interest instruction, however, interactive text/table and volumetric tools performed better on some outcomes than an interactive line-graph tool [5]. A risk-diversification experiment also found no uniform

superiority for its interactive visual treatment [6]. Representation–task alignment is therefore more credible than technological novelty.

This selective technical narrative review connects work on graphical perception, interaction, multimedia learning, accessibility, and narrative framing with studies of compound interest, diversification, retirement tools, and financial-knowledge interventions. It covers principles, applications, risks, evaluation, and future directions. Professional forecasting terminals, automated trading dashboards, and expert market-surveillance tools are outside the scope. No original dataset, visualization, experiment, effect estimate, or causal analysis is presented.

2 TECHNICAL AND INSTRUCTIONAL FOUNDATIONS

2.1 Begin with the Financial Model

An educational visualization is the visible surface of a financial model, so its credibility begins before any chart is drawn. Consider compound accumulation:

$$FV = P(1 + r/m)^{mt}, \quad (1)$$

where P is principal, r is the annual nominal rate, m is compounding frequency, and t is time. Sliders can expose sensitivity to each parameter but conceal assumptions. Omitting fees, taxes, inflation, missed contributions, rate changes, or uncertainty may leave the equation correct while making the display unsuitable for a real decision.

The same principle applies elsewhere. Loan displays need amortization, timing, fees, and variable-rate rules; budgets need consistent time units and irregular expenses; diversification needs correlations or joint scenarios; and retirement projections need contribution, return, inflation, longevity, and withdrawal assumptions. Historical data, simulations, forecasts, and user inputs should be labeled separately because they have different evidential status.

Educational simplification must preserve the relationship being taught. Progressive disclosure can begin with a few variables and reveal additional assumptions later. Simplification should reduce extraneous complexity, not reverse incentives or present one uncertain path as a promise.

2.2 Visual Encoding and Graphical Perception

Visual encoding maps values to position, length, angle, area, color, shape, or motion. Graphical-perception experiments found judgments based on position along a common scale generally more accurate than judgments based on angle or area [7]. Thus, exact comparisons of interest costs, asset weights, or spending are often better served by aligned bars, dots, or lines than by decorative areas.

Interpretation also depends on prior knowledge, conventions, attention, and task demands. Viewers combine bottom-up features with top-down expectations and may use fast heuristics unless a task encourages deliberate comparison [8]. A steep line may appear alarming on a narrow range, green may imply safety without evidence, and a small annual fee may look harmless until its long horizon is shown.

Axes, units, baselines, and time intervals should remain visible. Nominal and real values need explicit labels; color should encode a defined variable and include text or shape cues. Logarithmic scales require explanation, while normalized views should preserve raw values and denominators. The relevant benchmark—such as principal beside total repayment or real beside nominal wealth—should remain visible.

2.3 Interaction as a Reasoning Loop

Users can first inspect the overall pattern, then narrow the display to relevant observations and retrieve case-specific information [9]. Interaction taxonomies add intentions such as selecting, exploring, reconfiguring, encoding, filtering, connecting, and changing detail [10]. In financial education, these operations matter only when they support a reasoning step.

A productive loop is **predict** → **manipulate** → **observe** → **explain** → **compare** → **transfer**. Before moving a rate slider, the learner predicts the direction and approximate size of change. Linked views update, the learner explains the change, compares a baseline, and applies the relationship to a new case. The action thereby tests a mental model.

Unstructured exploration can produce shallow trial and error. Animation may emphasize movement rather than magnitude, and simultaneous controls can hide causation. Early practice can constrain one parameter at a time, preserve a baseline, allow undo, record assumptions, and request an explanation before revealing an optimized choice.

2.4 Visualization Literacy and Scaffolding

Visualization literacy includes reading, interpreting, evaluating, and constructing data representations [11]. Interactive visualization literacy additionally requires understanding how filters, transformations, navigation, and linked views change the evidence shown [12].

Financial and visualization literacy therefore interact. A learner may understand interest but misread a nonlinear curve, or read a distribution without understanding financial risk. Scaffolds can name encodings, demonstrate one comparison, reveal formulas, explain filters, and ask what remained constant. They should fade toward independent interpretation.

2.5 Cognitive Load and Representational Coordination

Interactive systems combine prose, formulas, charts, tables, controls, annotations, and feedback. Multimedia-learning research recommends coherence, signaling, segmentation, pretraining, and coordination of verbal and visual information to manage overload [13]. A dense dashboard can overwhelm working memory even when each element is relevant.

Complexity should be staged rather than removed. A sequence might show principal and interest, then contributions, inflation, and finally return uncertainty. Consistent labels should connect formulas, charts, and tables without redundant narration. Representational visuals can ground abstract concepts, but their educational value still requires validation for the intended learners and task [14].

Table 1 links representative financial concepts to models, encodings, interactions, and common misconceptions.

Table 1 Visualization Designs for Core Financial Literacy Concepts and Misconceptions

Financial concept	Required model or data	Candidate representation for evaluation	Purposeful interaction	Misconception to diagnose
Compound growth	Principal, rate, frequency, contribution, and time	Line chart plus cumulative contribution–growth decomposition	Adjust one parameter, preserve baseline, inspect values by year	Growth is linear or rate and time have proportional effects
Budget and cash flow	Dated income, fixed and variable expenses, irregular shocks	Calendar or time series with aligned category bars and running balance	Filter categories, move a shock, compare planned and actual cash	Annual affordability implies month-by-month liquidity
Debt amortization	Balance, annual percentage rate, fees, payment rule, and term	Balance trajectory plus stacked principal–interest payments	Change payment or rate and compare total cost and payoff date	A lower installment always means a cheaper loan
Risk and diversification	Return scenarios, weights, volatility, and correlation	Distribution, scenario paths, and risk–return comparison	Reweight assets, replay matched scenarios, inspect downside outcomes	More assets automatically mean effective diversification
Retirement adequacy	Contributions, returns, inflation, fees, withdrawals, and longevity	Fan chart or outcome distribution with real-income benchmark	Compare assumptions and stress scenarios rather than one forecast	The median projection is a guaranteed future balance

3 LEARNING APPLICATIONS

3.1 Compound Interest and the Time Value of Money

Compound interest is nonlinear and time-dependent. A linked interface can show the formula, yearly values, a growth curve, and contributions versus returns. Learners can compare compounding frequencies, observe the benefit of earlier contributions, and distinguish percentage from monetary change.

In a laboratory experiment with 86 undergraduates, Hubbard, Matthews, and Samek compared three interactive tools with real-time feedback: text/table, line-graph, and volumetric displays [5]. The text/table and volumetric conditions produced stronger immediate accuracy and larger reductions in simple-interest misconceptions than the line graph. The small sample and absence of delayed or behavioral outcomes support task-specific comparison of encodings, not a general ranking of text and graphics.

3.2 Budgeting, Cash Flow, and Debt

Budget education can combine temporal and categorical views. A calendar can reveal a short-term cash deficit hidden by an adequate annual total; aligned bars can compare planned and actual spending; and a running balance can expose irregular expenses. Filters need a persistent total so that hiding a category is not mistaken for eliminating it.

Debt tools can connect installment, term, total interest, and outstanding balance. Showing only the installment encourages a narrow affordability judgment; holding principal constant exposes how a lower payment may extend the term and raise total cost. Before displaying amortization schedules, the interface can ask learners to predict the cheaper option.

Direct debt evidence is limited but not absent. In a randomized experiment with 108 analyzed participants, four infographics improved immediate debt-literacy scores, with gains related to numeracy [15]. The small, selective sample, immediate posttest, and absence of behavioral or delayed outcomes limit generalization. A larger visual-explanation experiment also found short-term knowledge gains [4], while the wider evidence varies in topic and evaluation [3].

3.3 Risk, Return, and Diversification

Risk education is vulnerable to misleading summaries. One historical path can make a portfolio appear skillfully selected, while an average return conceals dispersion and downside risk. Matched scenarios can compare portfolios

under the same path and one portfolio across many paths. Distributions and loss frequencies should accompany numerical risk measures.

Lusardi and colleagues randomized 892 adults among four risk-diversification materials and a control [6]. All interventions increased self-efficacy, but objective outcomes differed: the video and brochure increased correct-answer rates, whereas the interactive tool reduced “do not know” responses without increasing correct answers. In a separate incentivized allocation experiment—not a teaching intervention—Wesslen and colleagues found that evaluation period and uncertainty format changed portfolio choices [16]. Together, the studies reject a general advantage for interactivity and warn that display design can steer risk-taking without proving improved risk literacy or transfer.

A diversification interface needs asset weights, correlation, scenario dependence, and downside outcomes. More securities do not ensure diversification when returns move together. Learners should explain how imperfect co-movement reduces portfolio variance, while scenario generators disclose correlation, tail-event, and distribution assumptions.

3.4 Retirement and Pension Planning

Retirement planners integrate contributions, retirement age, allocation, expected returns, fees, inflation, and withdrawals, making distant consequences and possible income gaps salient.

In an online-panel experiment, greater planner interactivity increased clicks and stated intention to revisit pension information, with heterogeneous preferences; it did not establish improved knowledge or saving [17]. In a separate trial, a bundled calculator treatment added projected income, a salient target gap, and interactive contribution scenarios. It increased average annual contributions, with larger effects among participants with higher financial knowledge, but the effect cannot be assigned to interactivity alone [18]. A randomized encouragement study with two Dutch pension funds found that encouragement to visit a personalized dashboard increased pension knowledge and self-efficacy among survey respondents, but not preparation, forecast accuracy, or intention to act [19]. Instrumental-variable estimates for actual use were positive for compliers, but only 10% of encouraged participants visited the dashboard and 16.7% completed the outcome survey; the estimates therefore should not be generalized to all plan participants. These findings distinguish selective knowledge, engagement, and behavioral outcomes.

Retirement views can pair a median with percentile bands, stress scenarios, and a real-income target. Learners can compare contributions, horizon, fees, and return uncertainty without treating probability as a promise. Advice-like outputs require a boundary between education and personalized guidance.

3.5 Data Storytelling and Learner-Facing Dashboards

Narrative visualization can guide a complex concept before allowing exploration. Design patterns balance author-driven explanation with reader-driven discovery [20]. A debt story might show one minimum payment, reveal accumulated interest across years, and then let the learner test alternatives.

Narrative authority can frame a conclusion through selection, emphasis, sequence, annotation, and omission [21]. Graphical presentation can also affect attitudes, with effects depending on issue and viewer [22]. A financial-literacy story therefore needs disclosed assumptions, clear separation of facts and scenarios, and meaningful counterviews.

Learner dashboards can integrate progress, misconceptions, and suggested actions, but many systems report activity without establishing learning effects [23]. Each metric needs a stated competency and actionable interpretation. Time, clicks, and completion indicate use, not independently financial knowledge or transfer.

4 A MODEL-ALIGNED DESIGN AND EVALUATION FRAMEWORK

The synthesis follows a traceable chain: **financial decision** → **validated financial engine** → **task-aligned encoding** → **guided learner action** → **diagnostic feedback** → **independent transfer assessment**. Assessment returns evidence to design through **learner error** → **misconception diagnosis** → **mechanism-based feedback** → **scaffold adjustment** → **retest** → **subgroup and error audit** → **redesign**.

4.1 Define the Financial Decision and Learning Outcome

Development begins with a demonstrable outcome, not a chart type. Instead of “understand debt,” a learner might compare two loans, identify total cost, explain the trade-off, and apply the method to a new pair. The context determines variables, benchmarks, simplification, and error costs.

Outcomes include knowledge, calculation, visual interpretation, explanation, decision quality, confidence calibration, retention, transfer, and behavior. A correct choice may lack understanding, while a different choice may reflect a legitimate liquidity constraint. The design must not encode one preference as universal when risk tolerance, horizon, and constraints differ.

4.2 Build and Expose a Valid Financial Engine

The computational layer documents data sources, formulas, scenarios, updates, rounding, missing data, and assumptions. Tests cover boundaries, monotonic relationships, accounting identities, and exceptions. For example, increasing a fixed

payment cannot lengthen payoff when other assumptions remain constant; portfolio weights and correlations must remain consistent; and retirement projections must distinguish nominal from real values.

Transparency means users and instructors can inspect assumptions that affect a conclusion. Saved scenarios retain parameters and data versions; defaults identify their source and permit sensitivity analysis. Claims remain limited to the implemented model.

4.3 Align Encoding, Interaction, and Scaffolding

The task determines the visual channel: exact comparison favors common scales, change favors time series, and uncertainty requires distributions or multiple scenarios. Each interaction corresponds to a stated question. Linked views preserve units and selection states so that one filter does not silently redefine another.

The learner then predicts, manipulates limited parameters, observes linked evidence, explains the change, receives feedback targeted to the diagnosed misconception, and solves a transfer case with reduced support. Equivalent accessible representations are part of this cycle from the start.

4.4 Evaluate Beyond Usability and Immediate Accuracy

Usability is necessary but insufficient. Evaluation distinguishes interface operation, display interpretation, financial learning, retention, transfer, uncertainty calibration, decision process, and appropriate behavior. A new visualization is best compared with a well-designed table, worked example, or calculator, not only with no instruction.

Process logs reveal changed assumptions, baseline comparisons, and revisions, but repeated slider movement can mean hypothesis testing or confusion. Independent explanations, novel cases, delayed tests, and matched scenarios provide stronger evidence. Results also require subgroup and error audits across prior knowledge, numeracy, visualization literacy, language, device, disability, and socioeconomic context.

Table 2 summarizes the framework and the inference boundary at each stage.

Table 2 Development, Evaluation, and Inference Boundaries for Interactive Financial Literacy Visualizations

Development stage	Required artifact or evidence	Appropriate evaluation	Inference that should not be made
Learning specification	Defined financial task, misconception, learner group, and transfer target	Expert review and baseline assessment	A topic label such as “investing” defines a measurable competency
Financial engine	Versioned formulas, assumptions, data, and test cases	Numerical verification, sensitivity tests, and domain review	An attractive output proves the underlying model is valid
Visual encoding	Task–channel rationale, units, baselines, labels, and alternative views	Graph-reading accuracy and error analysis	General perceptual guidance guarantees finance learning
Interaction and scaffolding	Prediction, manipulation, comparison, explanation, feedback, and fading plan	Usability plus observation of reasoning processes	More controls or clicks imply deeper engagement or understanding
Diagnostic revision	Error–misconception map, targeted feedback, scaffold rule, and redesign record	Independent retest and subgroup error audit	A corrected in-tool response proves transfer
Immediate learning	Independent knowledge, calculation, interpretation, and explanation tasks	Pre/post or controlled comparison with uncertainty estimates	A satisfaction score establishes financial literacy
Transfer and retention	Delayed and novel cases outside the practiced interface	Near- and farther-transfer tasks and follow-up measures	Correct in-tool performance will persist in real decisions
Behavioral use	Clearly defined, ethically appropriate financial action	Field observation or validated records with contextual analysis	Any behavioral change is beneficial or caused solely by the visualization

5 CHALLENGES AND RISKS

5.1 Visual Distortion and False Precision

Financial displays can mislead through truncated axes, inconsistent intervals, dual scales, area encodings, selective windows, or omitted benchmarks. Responsive layouts may change apparent volatility or slope, while filters can create survivorship bias. Axis state, transformations, and sample coverage need to remain visible.

False precision is equally dangerous. A precise retirement balance may appear certain despite uncertain returns and longevity, while a two-decimal risk score can hide model error and disputed assumptions. Numerical precision needs to match evidential precision.

5.2 Cognitive Overload and Interaction Costs

Small screens, animation, linked views, and numerous sliders can fragment attention. Hidden hover content disadvantages touch, keyboard, and novice users. Progressive disclosure, stable baselines, undo, concise instructions, and tabular alternatives can reduce these costs.

Interaction also changes the evidence: filtering losses, changing the horizon, or selecting successful assets creates a different view. Transformations need reversible histories, and assessment logs need semantic states rather than only coordinates and clicks.

5.3 Heterogeneous Learners and Unequal Benefits

Financial knowledge, numeracy, graph literacy, language, experience, and device access vary. In Goda et al.'s bundled calculator intervention, contribution increases were larger among participants with higher financial knowledge [18]. This subgroup result makes distributional evaluation necessary but does not generalize to every retirement tool.

Adaptive support may misclassify exploration as difficulty or silently provide unequal opportunities. Its rules need to be inspectable, reversible, and evaluated across groups, without assigning permanent ability labels.

5.4 Accessibility

Color-only status, mouse-only interaction, and charts without textual structure exclude users with disabilities. Accessible visualization research covers navigation, description, sonification, data access, and multimodal interaction [24]. Alternative text must communicate structure and meaningful trends, not merely announce that a chart exists [25].

Defensible tools provide keyboard operation, visible focus, sufficient contrast, non-color cues, scalable text, reduced motion, structured tables, downloadable data, and concise descriptions of purpose, axes, patterns, and uncertainty. Alternative representations can improve comprehension for many learners.

5.5 Privacy, Persuasion, and Governance

Personalized tools may collect income, debt, spending, assets, household status, and interaction histories. These sensitive data require minimization, protection, limited retention, and separation from commercial profiling. Classroom policies need clear access, consent, grading, and deletion rules.

Commercial conflicts also matter. Defaults, windows, fees, or risk assumptions can favor a sponsor while appearing educational, and narrative graphics can intensify this effect [21-22]. Governance requires disclosure of sponsorship, methods, product universe, defaults, and recommendation logic, together with a clear boundary among education, advice, and marketing.

6 FUTURE DIRECTIONS

6.1 Uncertainty-First Financial Visualization

Future tools can make uncertainty a primary learning object. Scenario ensembles can compare historical resampling, parametric simulation, and stress cases while explaining their assumptions. Learners can interpret probabilities, ranges, tail losses, and model disagreement before justifying decisions across plausible futures.

6.2 Transparent Adaptive Scaffolding

Adaptive systems can select examples, prompts, and representations from diagnosed misconceptions. The rule remains tied to an explicit competency and explains why support changed. For example, a year-by-year view may address misread curvature before an independent line-chart retest. Adaptation should not optimize platform time or narrow content from a few clicks.

6.3 Multimodal and Accessible Interaction

Visualization literacy can include coordinated visual, textual, tabular, tactile, and auditory access. Language summaries, sonification, and keyboard exploration can expose structure and change, but generated descriptions require data checks because fluency may conceal omission or reversal. Every statement needs a trace to values and assumptions.

6.4 Transfer-Centered and Longitudinal Evidence

Future studies need strong comparison materials, preregistered outcomes where appropriate, delayed tests, novel cases, and confidence calibration. Ethical behavioral observation can help when no single action is presumed optimal for every learner. Reporting must separate immediate interpretation, retained knowledge, transfer, decision quality, and behavior.

6.5 Reproducible Educational Benchmarks

Shared benchmarks could cover compound growth, loans, cash-flow timing, diversification, and retirement uncertainty at several difficulty levels. Repositories can version data, formulas, defaults, interface states, accessibility descriptions, and assessments. Tasks should include plausible misleading views and test why they mislead, not only value extraction from good charts.

7 REVIEW LIMITATIONS

This technical synthesis draws on selected literature and is neither an exhaustive systematic review nor a quantitative meta-analysis. It combines direct financial-literacy interventions with general research on graphical perception, interaction, multimedia learning, narrative visualization, learning dashboards, and accessibility. These sources differ in participants, topics, media, comparison conditions, and outcome measures. Several direct studies emphasize immediate knowledge, engagement, intention, or contributions in one setting; they do not establish durable effects across all learners or financial decisions. The proposed framework is a synthesis and requires local validation against curriculum, population, technology, and policy. No original visualization, learner dataset, experiment, or causal estimate is presented.

8 CONCLUSION

Interactive data visualization can make financial relationships available for inspection and inquiry. Learners can observe compound growth, connect monthly payments with total debt cost, compare cash-flow timing, explore diversification under matched scenarios, and examine retirement outcomes across uncertain futures. These capabilities are educationally useful because they connect symbolic models with visible consequences and allow assumptions to be tested.

The value does not arise from graphics or interaction alone. A valid financial engine precedes the display; encoding matches the comparison; interaction supports prediction and explanation; scaffolding develops financial and visualization literacy; and evaluation extends beyond immediate accuracy. In one small undergraduate experiment, interactive text/table and volumetric tools outperformed an interactive line graph on immediate compound-interest outcomes, while retirement-tool studies produced different patterns across learners and outcome measures. These context-specific results establish neither a general ranking of representations nor a universal benefit of interactivity.

Future systems should foreground uncertainty, preserve inspectable assumptions, provide equivalent accessible representations, and test retention and transfer. When these conditions are met, interactive visualization is not a decorative supplement or an automated answer generator. It is a disciplined learning environment in which financial models can be explored, challenged, explained, and applied.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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REFERENCES

- [1] Lusardi A, Mitchell O S. The Economic Importance of Financial Literacy: Theory and Evidence. *Journal of Economic Literature*, 2014, 52(1): 5-44. DOI: 10.1257/jel.52.1.5.
- [2] Kaiser T, Lusardi A, Menkhoff L, et al. Financial Education Affects Financial Knowledge and Downstream Behaviors. *Journal of Financial Economics*, 2022, 145(2): 255-272. DOI: 10.1016/j.jfineco.2021.09.022.
- [3] Du M, Amor R, Ma K L, et al. Data Visualization for Improving Financial Literacy: A Systematic Review. *Visual Informatics*, 2026, 10(1): 100272. DOI: 10.1016/j.visinf.2025.100272.
- [4] Kothakota M G, Kiss D E. Use of Visualization Tools to Improve Financial Knowledge: An Experimental Approach. *Journal of Financial Counseling and Planning*, 2020, 31(2): 193-208. DOI: 10.1891/JFCP-18-00070.
- [5] Hubbard E, Matthews P, Samek A. Using Online Compound Interest Tools to Improve Financial Literacy. *The Journal of Economic Education*, 2016, 47(2): 106-120. DOI: 10.1080/00220485.2016.1146097.
- [6] Lusardi A, Samek A, Kapteyn A, et al. Visual Tools and Narratives: New Ways to Improve Financial Literacy. *Journal of Pension Economics and Finance*, 2017, 16(3): 297-323. DOI: 10.1017/S1474747215000323.
- [7] Cleveland W S, McGill R. Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. *Journal of the American Statistical Association*, 1984, 79(387): 531-554. DOI: 10.1080/01621459.1984.10478080.

- [8] Padilla L M, Creem-Regehr S H, Hegarty M, et al. Decision Making with Visualizations: A Cognitive Framework Across Disciplines. *Cognitive Research: Principles and Implications*, 2018, 3(1): 29. DOI: 10.1186/s41235-018-0120-9.
- [9] Shneiderman B. The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. *Proceedings of the 1996 IEEE Symposium on Visual Languages*, 1996: 336-343. DOI: 10.1109/VL.1996.545307.
- [10] Yi J S, Kang Y A, Stasko J, et al. Toward a Deeper Understanding of the Role of Interaction in Information Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 2007, 13(6): 1224-1231. DOI: 10.1109/TVCG.2007.70515.
- [11] Börner K, Bueckle A, Ginda M. Data Visualization Literacy: Definitions, Conceptual Frameworks, Exercises, and Assessments. *Proceedings of the National Academy of Sciences*, 2019, 116(6): 1857-1864. DOI: 10.1073/pnas.1807180116.
- [12] Firat E E, Joshi A, Laramée R S. Interactive Visualization Literacy: The State-of-the-Art. *Information Visualization*, 2022, 21(3): 285-310. DOI: 10.1177/14738716221081831.
- [13] Mayer R E, Moreno R. Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist*, 2003, 38(1): 43-52. DOI: 10.1207/S15326985EP3801_6.
- [14] Malik A, Fürstenau B. Representational Visuals of Abstract Financial Concepts: A Means to Foster Financial Literacy. *Citizenship, Social and Economics Education*, 2024, 23(3): 144-164. DOI: 10.1177/14788047241277768.
- [15] Porzak R, Cwynar A, Cwynar W. Improving Debt Literacy by 2/3 Through Four Simple Infographics Requires Numeracy and Not Focusing on Negatives of Debt. *Frontiers in Psychology*, 2021, 12: 621312. DOI: 10.3389/fpsyg.2021.621312.
- [16] Wesslen R, Karduni A, Markant D, et al. Effect of Uncertainty Visualizations on Myopic Loss Aversion and the Equity Premium Puzzle in Retirement Investment Decisions. *IEEE Transactions on Visualization and Computer Graphics*, 2022, 28(1): 454-464. DOI: 10.1109/TVCG.2021.3114692.
- [17] Brüggén E C, Post T, Schmitz K. Interactivity in Online Pension Planners Enhances Engagement with Retirement Planning—But Not for Everyone. *Journal of Services Marketing*, 2019, 33(4): 488-501. DOI: 10.1108/JSM-02-2018-0082.
- [18] Goda G S, Levy M R, Flaherty Manchester C, et al. Are Retirement Planning Tools Substitutes or Complements to Financial Capability? *Journal of Economic Behavior & Organization*, 2023, 214: 561-573. DOI: 10.1016/j.jebo.2023.08.001.
- [19] Kramer M, Lensink R, Plantinga A. Do Online Pension Dashboards Affect Pension Knowledge and Expectations? Evidence from a Randomized Survey Experiment. *Journal of Pension Economics and Finance*, 2024, 23(4): 504-527. DOI: 10.1017/S1474747224000040.
- [20] Segel E, Heer J. Narrative Visualization: Telling Stories with Data. *IEEE Transactions on Visualization and Computer Graphics*, 2010, 16(6): 1139-1148. DOI: 10.1109/TVCG.2010.179.
- [21] Hullman J, Diakopoulos N. Visualization Rhetoric: Framing Effects in Narrative Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 2011, 17(12): 2231-2240. DOI: 10.1109/TVCG.2011.255.
- [22] Pandey A V, Manivannan A, Nov O, et al. The Persuasive Power of Data Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 2014, 20(12): 2211-2220. DOI: 10.1109/TVCG.2014.2346419.
- [23] Bodily R, Verbert K. Review of Research on Student-Facing Learning Analytics Dashboards and Educational Recommender Systems. *IEEE Transactions on Learning Technologies*, 2017, 10(4): 405-418. DOI: 10.1109/TLT.2017.2740172.
- [24] Kim N W, Joyner S C, Riegelhuth A, et al. Accessible Visualization: Design Space, Opportunities, and Challenges. *Computer Graphics Forum*, 2021, 40(3): 173-188. DOI: 10.1111/cgf.14298.
- [25] Jung C, Mehta S, Kulkarni A, et al. Communicating Visualizations without Visuals: Investigation of Visualization Alternative Text for People with Visual Impairments. *IEEE Transactions on Visualization and Computer Graphics*, 2022, 28(1): 1095-1105. DOI: 10.1109/TVCG.2021.3114846.